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LARGE INFECTED SOLITARY PULMONARY CYSTS SIMULATING EMPYEMA

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LARGE infected solitary cysts of the lung are often erroneously diagnosed as encapsulated empyema before operation, and at times the true condition is not recognized during or after operation. In this paper the cases of three patients with large intrapulmonary cysts lined by epithelium and containing purulent material are reported. At the time the patients came under our observation the clinical condition simulated an empyema and had been diagnosed as such. Two of the three were treated by us as empyema patients for some time before the correct diagnosis was realized. A differentiation of the two conditions is of clinical importance, for drainage alone will not produce obliteration of epithelialized cysts. In order to bring about complete healing, two patients required lobectomy, and the third, enucleation of the cyst.

The term "cystic disease of the lung" has been applied to a wide variety of abnormal localized distentions of parts of the bronchial tree and pulmonary parenchyma, such as congenital cystic disease of the lung, acquired cystic disease of the lung, cystic bronchiectasis, bullous emphysema, pleural blebs, chronic interstitial pneumonitis with emphysema and pulmonary pneumatoceles. An exact clinical differentiation between these types of lesions is not always possible, and the confusion in terminology which now exists is due in part to the fact that some of the above-mentioned lesions represent varying degrees of similar pathologic processes.

Until recently the term *congenital* cystic disease of the lung had been employed frequently for any intrapulmonary cyst formation. Peirce

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and Dirkse,[6] however, have stressed the fact that cystic disease may be of the acquired type, secondary to infection of the pulmonary parenchyma or to partial bronchial obstruction. It is frequently difficult in a particular case to ascertain clinically whether the lesion is congenital or acquired, unless, in the case of an acquired cyst, normal roentgenograms happen to have been obtained before the onset of the symptoms.

Pulmonary cysts may contain fluid, air, or both; air-containing cysts are the more common, and multiple air-containing cysts, which are more frequently encountered than single air cysts, are usually not difficult to recognize roentgenographically. The majority of large air cysts do not have an epithelial lining. Infection may be superimposed upon such a cyst, with resultant accumulation of pus within the cavity and surrounding pneumonitis. The air-containing cysts which do not have an epithelial lining and which have been variously designated as cystic disease of the lung, balloon cysts, and pneumatoceles must be clearly differentiated from the epithelialized cysts reported in this paper, for the pathologic characteristics, clinical behavior, and treatment are different in the two groups.

PATHOLOGY

Pulmonary cysts may be classified into two groups according to the presence or absence of an epithelial lining. The epithelialized cysts may be congenital or acquired. The wall of a congenital epithelialized cyst may contain bronchial elements, such as cartilage, glands, and smooth muscle; the epithelium is bronchial in type, unless replaced by squamous epithelium due to metaplasia or destroyed by infection. The acquired epithelialized cyst usually does not have cartilage and muscle in the wall; epithelialization results from an ingrowth of epithelium from the bronchial fistulas in the same manner as in an epithelialized chronic pulmonary abscess.

The nonepithelialized pulmonary cyst has a wall consisting merely of thin connective tissue without epithelium. There may be some flattened connective tissue cells in areas presenting a mesothelial lining, but there are no bronchial elements in the wall. Compressed alveoli surround the thin connective tissue lining. There is no definite line of distinction between these pulmonary cysts or pneumatoceles and bullous emphysema. These cysts may diminish progressively in size and disappear spontaneously, or they may become inflated to a huge size by a ball-valve mechanism of the draining bronchus. Although cysts without epithelial lining may persist unchanged for years, the important consideration is that, with a change in the bronchial mechanism, the cyst may disappear without any treatment. The nonepithelialized type of pulmonary cyst is mentioned here only in differentiation from epithelialized cysts.

The three pulmonary cysts described in this paper were lined, for the most part, by stratified columnar epithelium. Key[5] and others have

called these lesions bronchiogenic cysts. There were some areas of the cyst wall in our cases which were denuded of epithelium, apparently as a result of the inflammatory process. In two of our cases the cyst wall also contained smooth muscle and elastic tissue as demonstrated by special stains. Lymph follicles were present in one case. In each of our three cases the cyst was large. In one instance it occupied the lower half of the right lower lobe; in another instance it occupied the site of the middle lobe and caused partial compression of the upper and lower lobes; and in the third case almost the entire left lower lobe was replaced by the cyst. One of the cysts had no apparent bronchial communication, while the other two had numerous small bronchial fistulas and presented the appearance of a lattice lung on the inner aspect.

A striking characteristic of an epithelialized pulmonary cyst is its failure to diminish appreciably in size over long periods of time despite adequate drainage. Persistence of intrapulmonary cavities may be due to one or more of the following factors: (1) positive intracavitary pressure; (2) progressive destructive process within the lung; (3) loss of expansibility of surrounding pulmonary tissue; (4) elastic properties of the cavity wall; (5) epithelialization of the cavity wall. In our cases positive intracavitary pressure was eliminated as a factor in preventing collapse of the cyst, for all cases were treated by adequate open drainage for long periods of time without significant effect upon the size of the cavity. A progressive destructive process in the lung was not present, and loss of expansibility of surrounding pulmonary tissue was not an important factor inasmuch as moderate expansion of the adjacent lung occurred after removal of the cyst. The role of muscle and elastic tissue as factors in the persistence of intrapulmonary cavities is not certain, but these elements are apparently not of great importance as is demonstrated by the failure of epithelialized cavities to close when muscle or elastic tissue is not present. Therefore, the epithelial lining must be regarded as the most important factor. Following removal of the epithelialized cyst wall, obliteration of the space readily occurs. Healing is accomplished for the most part by granulation, with elevation of the diaphragm, retraction of the thoracic wall, and shifting of the mediastinum, and to some extent by the expansion of the adjacent pulmonary tissue. The importance of each of these factors varies in different cases.

DIAGNOSIS

The preoperative differentiation of a large infected pulmonary cyst and empyema is not always possible. Most of the reported epithelialized pulmonary cysts have occurred in children or young adults. Patients with a pulmonary cyst are likely to have had previous respiratory symptoms, and this history may date back to early life. The respiratory infections have usually been considered, in retrospect, as secondary to a

pre-existing congenital pulmonary abnormality. This interpretation, however, is not always correct because in some cases the cyst is the result, rather than the cause, of the previous infection.

The acute illness usually begins as a respiratory infection. Sputum, if present, may be profuse with the patient in certain positions which favor drainage of the purulent accumulation, but a history of copious expectoration of purulent material does not aid in the differentiation of infected pulmonary cyst and empyema with bronchopleural fistula. Physical examination of the chest is also unlikely to enable one to differentiate between an infected pulmonary cyst and an empyema, although marked retraction of the thoracic wall and approximation of the ribs are more suggestive of empyema. Thoracentesis usually yields pus without difficulty, but the character and culture of the pus may be similar to that seen in empyema.

The roentgenologic examination is frequently of great aid in the differentiation of empyema and infected pulmonary cyst, but the two lesions cannot be distinguished by this means in some cases. The contour of the fluid pocket is often of differential diagnostic value in that the outline of a cyst is spherical or oval in both posteroanterior and lateral projections (as in Fig. 5), whereas the outline of an encapsulated empyema may be triangular or fusiform and conforms more to the contour of the thoracic cage or neighboring structures in the region it occupies. Little evidence of pleural thickening may be seen on the roentgenogram of a person with a pulmonary cyst even though the infection is of many months' standing (Fig. 9). The combined thickness of the cyst wall and pleura may be less than the thickness of the parietal pleura alone in cases of chronic empyema. If the infected cyst cavity is for the most part filled with air, the roentgenogram may show strands of pulmonary tissue traversing the cavity (Fig. 8), and the correct diagnosis should then be suspected. The presence of other pulmonary cysts, either fluid- or air-containing, may give a clue to the correct diagnosis. It must be remembered, however, that an infected pulmonary cyst and empyema may coexist.

At operation an absence of periosteal reaction on the inner surface of the overlying ribs may be noted in the case of an infected pulmonary cyst. This differential point is of greater significance if the infection has been present for a considerable length of time. Instead of finding the thickened parietal pleura characteristic of an empyema, the pleura may be quite thin. It may be noted that pulmonary tissue is traversed in reaching the pus; but this finding does not necessarily mean that one is dealing with an intrapulmonary process because the approach to an encapsulated empyema may be through pulmonary tissue if an improper drainage site is chosen, or if the empyema does not extend to the thoracic wall. Pulmonary tissue may be present or absent in the outer wall. If

present, it may be so thin that it can be recognized only microscopically. The presence of anthracotic pigment indicates the fact that pulmonary tissue is being incised; this was true in one of our cases. A biopsy will usually definitely establish the correct diagnosis. The wall of the bronchiogenic type of pulmonary cyst is usually lined by ciliated columnar epithelium, perhaps with areas of squamous metaplasia, and it may contain glands, smooth muscle, elastic tissue, lymph follicles, and cartilage. However, infection in a pulmonary cyst may cause destruction of the epithelial lining, so that in such instances a biopsy which does not show characteristic tissue does not rule out the possible existence of a pulmonary cyst.

At the time of drainage of a pulmonary cyst it may be noted that a portion of the cavity wall has the appearance of a lattice lung with multiple bronchial fistulas. The presence of many small bronchial fistulas on the inner surface of the cavity wall should be regarded with suspicion, although many fistulas may be present in an empyema with an associated pulmonary abscess which has ruptured into the pleural space. In cysts with the appearance of a lattice lung, cordlike strands sometimes extend across the cavity; this is well illustrated in Case 3 in this paper. These cordlike structures resemble the septa which are seen in multiloculated pulmonary abscesses, or the adhesions which contain pulmonary tissue in cases of pulmonary tuberculosis with pneumothorax. If a biopsy of one of these strands shows it to be covered completely by respiratory type of epithelium, the intrapulmonary nature of the lesion is demonstrated (Fig. 11).

If the true nature of the condition is not recognized at the time of the original drainage and the case is treated as an empyema, a striking feature in the postoperative course is the failure of the cavity to diminish progressively in size despite adequate drainage for months or years and without the presence of markedly thickened pleura (Fig. 9). An initial decrease in size usually occurs due to the fact that the contents of the cavity were under pressure before drainage was instituted. The cavity of a pulmonary cyst will maintain its spherical or oval shape after drainage (Fig. 5), in contrast to the usual elongated shape of an empyema cavity. Associated with the failure of the cavity to collapse, any mediastinal displacement to the contralateral side which was present before surgical drainage may remain to a greater or lesser extent. The diaphragm may not become elevated (Fig. 9), as it tends to in the healing of an empyema cavity. The smooth, shining wall of the cyst is also in contrast to the fibrotic or granulating surface of the interior of an empyema. A bronchogram following drainage of a cyst may be of aid in the differential diagnosis. In one of our cases (Case 3) in which the bronchogram demonstrated displacement of the bronchi in the adjacent

noncystic portions of the lung, the otherwise normal but displaced bronchi were elongated and arched around the cyst (Fig. 9).

Pulmonary cysts also may be confused with pulmonary abscesses. If operation is undertaken with the diagnosis of pulmonary abscess, the failure of the cavity to obliterate itself may be ascribed to secondary epithelialization of the cavity wall. The problem of both conditions is, however, essentially similar, and some so-called pulmonary cysts are actually epithelialized abscess cavities. Infected pulmonary cysts that are completely filled with pus may also be confused with tumors, but evidence of sepsis and determination of the character of contents establish the diagnosis. Examination of the contents will also differentiate pulmonary cysts from parasitic cysts within the lung. Aspiration of a presumed parasitic cyst is to be avoided, however, because of the danger of an anaphylactic reaction. Mediastinal cysts may usually be differentiated preoperatively by their location and bronchography; in some cases only the operative findings or histologic examination will establish the diagnosis.

TREATMENT

Treatment of large infected pulmonary cysts with an epithelial lining should consist first of surgical drainage of the purulent contents by thoracotomy. In cases of suspected cyst, a rib resection rather than an intercostal type of drainage should be done to enable the operator to visualize the interior of the cavity and to secure a biopsy. If the first biopsy specimen is inconclusive, another more satisfactory specimen should be obtained. With subsidence of the inflammatory process in the cyst, the smoothness of the lining wall may become more apparent grossly and the biopsy examination more satisfactory.

Several reports in the literature mention unsuccessful attempts to obliterate the large cavity which persists after drainage by various forms of collapse procedures such as a thoracoplasty and phrenicectomy. Collapse procedures are definitely contraindicated as the primary method of treatment in the obliteration of these cavities; healthy lung will be sacrificed, and an incomplete collapse of the cyst will result (Fig. 10).

The only procedures which result in obliteration of the pulmonary cavity are those which destroy or remove the epithelial lining. Chemical or electrosurgical cauterization of the epithelium might conceivably be effective, but we are not aware of any large, completely epithelialized cysts in which cauterization has been employed successfully. Furthermore, this method does not seem practical if numerous free bronchial communications are present and if there is a well-developed epithelialized wall with muscle and elastic tissue.

Removal of the cyst wall is the most certain method of treating the epithelialized pulmonary cyst. This may be done by removal of the lobe containing the cyst or by enucleation of the cyst itself. If no

definite line of cleavage around the cyst is present, lobectomy is the preferable procedure; otherwise, serious bleeding or air embolism may result. Lobectomy may be technically more difficult than the usual lobectomy for bronchiectasis. This was true in one of our cases, but not in the other. The patients are usually children or young adults, and they are, therefore, at an age period when major intrathoracic procedures are borne well. With the infected contents of the cyst drained, ample time should be taken to permit subsidence of the inflammatory reaction and to improve the patient's general condition before radical surgery is employed.

Occasional reports in the literature on the treatment of large infected epithelialized pulmonary cysts describe drainage of the purulent contents of the cyst, but at the time of the report a draining intrapulmonary cavity still remained. There is little information available as to the late results in these cases. The literature on the complete eradication of previously infected large pulmonary cysts lined by epithelium is not extensive, and most of the reports have appeared during the past few years.

Clairmont[2] reported a case of pulmonary cyst in a 10-year-old boy. A diagnosis of pneumonia complicated by an interlobar empyema had been made. After several operations the intrapulmonary character of the lesion was recognized. The patient died following an attempted excision of the cyst.

Sauerbruch[7] mentions four patients who were referred to him as chronic empyema cases after numerous operations had been performed. In the first two cases thoracoplasty was first done, with unfavorable results. All four cases were then subjected to lobectomy or resection of the cyst and were cured.

Sergent and co-workers[8] reported three cases of large infected pulmonary cysts. Surgical therapy was unsuccessful in these cases, and they stress the great danger of radical excision of the cysts.

Harrington[4] has reported a cyst of an azygos lobe with bronchial communication. The case was successfully treated by opening of the cyst and excision of its walls.

Burnett[1] reported an infected cyst of the right lower lobe in a young female. The large, smooth cavity with multiple bronchial fistulas persisted after drainage. Two years later the thick cyst wall was excised, with rapid closure of the residual space.

Taylor[9] reported a large pulmonary cyst of the right lower lobe which was first treated by drainage under the diagnosis of empyema. Later the cyst was enucleated, and the wound healed completely.

Gunby[3] reported a case of solitary pulmonary cyst which was finally recognized and cured by excision.

Key[5] has recently reported three cases of bronchiogenic pulmonary cyst which were treated by lobectomy. Each of the patients had been sent to him with the diagnosis of chronic empyema, and he points out the confusion which may arise in diagnosis. His first case was that of a 10-year-old boy with a large cyst of the left lower lobe which had been draining for more than four years. Injection of iodized oil into the large cavity revealed several smaller cavities. Lobectomy was done. The wall of the cyst contained fibrous connective tissue and stratified cylindrical epithelium. The patient did well following operation.

Key's second case was that of a 13-year-old boy. In the right lower lobe there was a large intrapulmonary cavity which had been drained repeatedly for nine years. Lobectomy was performed successfully. The cyst wall was lined with respiratory epithelium.

Key's third case was that of a 10-year-old boy who had had repeated drainages for supposed empyema during three years. There was a cyst of the left lower lobe. Because the surrounding adhesions were firm, lobectomy seemed quite dangerous. An attempt was made, therefore, to destroy the epithelial lining by painting with 20 per cent silver nitrate on several occasions in the hope that the walls would fuse after a plastic operation. This was not successful. Later, during an attempted lobectomy, the patient died of air embolism. The pulmonary cavity was lined by cubical epithelium, and a few muscle fibers were present in the wall. On the basis of the unfavorable outcome in his third case, Key suggested that a tourniquet be placed around the lobar hilum as the first step of the operation in difficult cases. This, he felt, would reduce the danger of air embolism and permit the operation to be discontinued at any time, if necessary.

We believe that the microscopic evidence in the three cases reported in this paper favors the congenital origin of the cyst in these instances. In each of the cases, the cyst had been drained for more than two years before it was removed. In two of the three cases, lobectomy was performed; in the third case the cyst was enucleated. At present all of the patients are well and have healed thoracic wounds.

CASE REPORTS

CASE 1.—J. P. (No. 404350), male, aged 16 years, was admitted June 21, 1937. At the age of 7 years a diagnosis of "tuberculosis" had been made on the basis of physical examination only. He had had measles and whooping cough in early childhood. There was no history of pneumonia or severe upper respiratory infection before the onset of the present illness. In May, 1935, the patient had pain in the right side of the chest. Cough developed several days later, particularly on lying down. A right thoracentesis was done shortly after the onset of illness, and thin, yellow, bloodstreaked fluid was removed. Thoracotomy was performed and the pus evacuated. Ten weeks later the drainage tube was removed. The wound closed, but the patient did not seem entirely well. In January, 1936, he again noted cough on lying down. Another drainage tube was inserted and left in place.

In the spring of 1937, during a paroxysm of coughing he raised some thick, yellow, nonfoul sputum. The drainage tube, which had apparently been plugged for some time, was removed, and considerable pus gushed out. Shortly thereafter the patient was admitted to the University Hospital.

Physical examination revealed a normally developed boy of 16 years. He was pale, but did not appear ill. The lower half of the right hemithorax was depressed. On the lateral aspect of the right lower part of the chest there was an operative scar, with a draining sinus large enough to admit a finger. There was evidence of a previous costal resection in this region. Yellow, nonodorous pus drained from the sinus. When the patient was lying on the left side, he coughed up similar material. There was considerable respiratory lag of the right chest. Dullness and diminished breath sounds were noted over the lower half of the right chest, especially posteriorly. No clubbing of the fingers was present. A clinical diagnosis of chronic empyema with bronchopleural fistula was made.

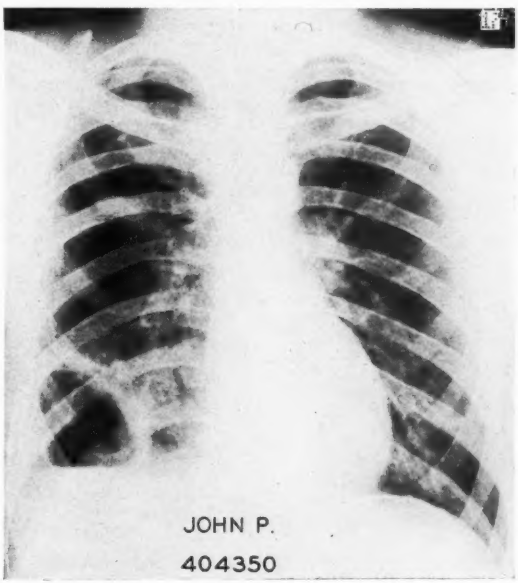

Fig. 1.—Case 1. June 21, 1937. Roentgenogram shows cavity with a fluid level in lower portion of right hemithorax. The cavity has a rounded contour. The absence of narrowing of the interspaces and the small amount of "pleural thickening" are suggestive of pulmonary cyst in contradistinction to empyema, in view of the fact that the cavity had been draining intermittently for more than two years.

Roentgenograms of the chest showed a cavity with a fluid level in the lower lateral portion of the right hemithorax. This was interpreted as a chronic empyema. It should be noted, however, that the contour of the cavity was unusual and there was not much pleural thickening (Fig. 1). The remainder of the lung fields showed nothing remarkable.

Operation was decided upon, with the object of improving the drainage of the cavity; it was performed on June 23, 1937. Immediately before operation the patient was tilted so that the pus within the cavity was evacuated through the chest wall drainage site, in order to prevent flooding of the bronchial tree through

the bronchial fistulas during the operation. Under gas and oxygen anesthesia, an additional segment of the seventh and a portion of the eighth rib were resected. The ribs showed no periosteal reaction. Upon enlarging the opening into the cavity, it was obvious that a layer of pulmonary tissue about 2 mm. in thickness lined the outer portion of a pulmonary cavity in the region of the previous thoracotomy opening. The thin layer of lung could be separated easily from the slightly thickened pleura. Anthracotic pigment was present in the pulmonary tissue. Several biopsies were obtained. A fairly large opening was made into the cavity, and its interior was inspected. The cavity was spherical in shape, except for its lower portion which corresponded to the contour of the diaphragm. The cavity wall was so thin that the inner surfaces of the ribs were readily palpated through the interior of the cavity. The thin cyst wall adjacent to the diaphragm had a smooth appearance, more nearly resembling the appearance of normal diaphragm than that of an empyema cavity wall. On the medial aspect of the cavity a large number of small bronchial fistulas were present, and the appearance was that of a lattice lung. The pulmonary surface was smooth and appeared to be epithelialized. The cavity was loosely packed with gauze. The postoperative diagnosis was infected pulmonary cyst.

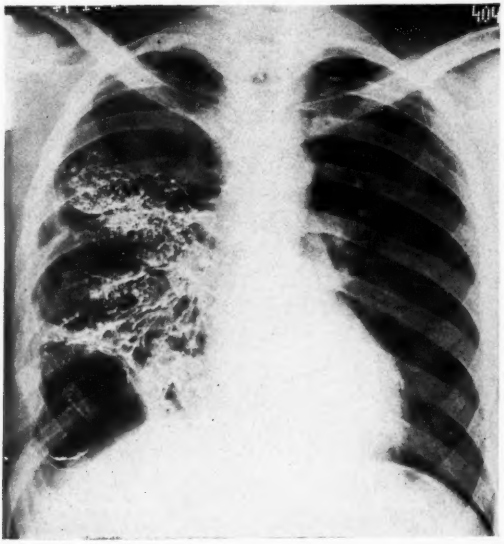

Fig. 2.—Case 1. July 19, 1937. Bronchogram one month after secondary drainage shows no significant change in the size or shape of the cavity and no bronchiectasis. Some lipiodol has entered the cyst through bronchial fistulas.

The biopsied tissue from the cavity wall revealed fibrotic pulmonary tissue showing chronic inflammation and dilatation of the bronchioles. One surface was covered in part by stratified squamous epithelium and in part by columnar epithelium. Cultures of the pus from the cavity showed *Streptococcus viridans, Staphylococcus aureus,* and an unidentified gram-negative bacillus.

The postoperative course was uneventful. There was no significant change in the size of the cavity following the establishment of more adequate drainage. A bronchogram demonstrated the bronchial fistulas opening into the cavity, but showed no evidence of bronchiectasis (Fig. 2).

On July 29, 1937, about five weeks after the previous operation, a right lower lobectomy was performed by Dr. John Alexander. The entire lower lobe was adherent, but the adhesions were relatively avascular, except around the thoracotomy site and over the diaphragm. The cyst wall was densely adherent to the diaphragm, and great difficulty was encountered in the dissection. A small portion of the cyst wall was left attached to the diaphragm as it could not be removed safely at the time. This remnant of cyst was thoroughly rubbed with 10 per cent formalin in an attempt to destroy the epithelium. The patient's condition after operation was only fair.

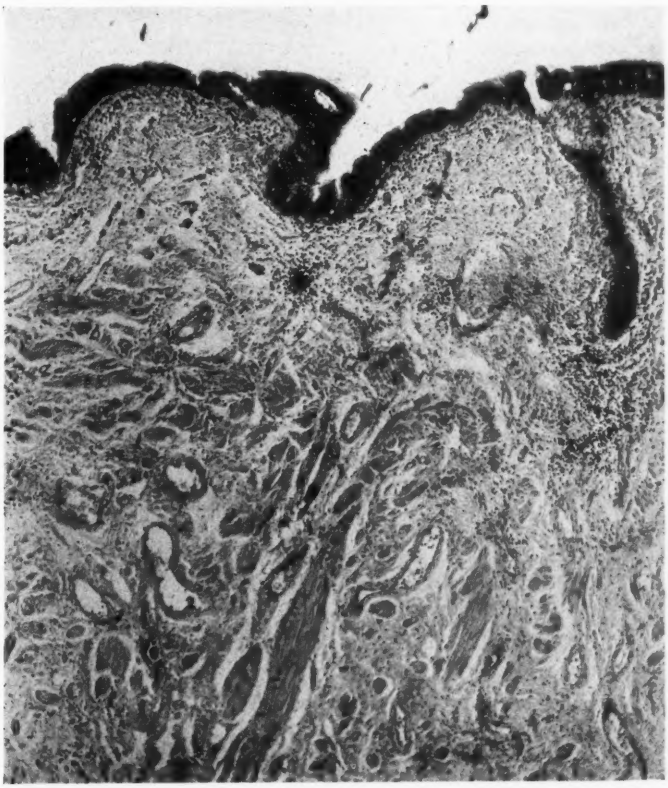

Fig. 3.—Case 1. Photomicrograph of wall of cyst showing respiratory epithelial lining and smooth muscle. Lymphocytic infiltration is present beneath the epithelium.

Pathologic examination showed a large cyst in the lower portion of the excised lobe. Numerous bronchi opened into the cyst. The remainder of the lobe appeared normal and showed no bronchiectasis. Microscopic examination of the cyst wall showed it to be lined by ciliated columnar epithelium (Fig. 3). Smooth muscle, elastic tissue, and lymph follicles were present in the wall.

Eleven days after the lobectomy, part of the wound was reopened in order to drain an empyema which did not communicate with the drainage tubes that had been inserted at the time of lobectomy. The patient improved slowly. The upper

lobe had partly collapsed at the time of the lobectomy, and postoperatively there was an apical pneumothorax pocket, but this was gradually obliterated by re-expansion of the upper lobe. The postoperative course was also complicated by recurrence of a phlebitis. A bronchial fistula which followed the lobectomy closed spontaneously in about four months. A small basal empyema cavity persisted. On April 30, 1938, a right temporary phrenic nerve interruption was done to aid in obliteration of the empyema cavity. On June 15, 1938, an extrapleural thoracoplasty with resection of portions of the seventh, eighth, and ninth ribs was performed for the same purpose. The postoperative condition was excellent, but the empyema cavity persisted, although reduced in size. On June 29, a Schede thoracoplasty was undertaken, and it was noted during the operation that a part of the diaphragmatic and medial wall of the empyema cavity was lined with epithelium. This layer of epithelium had apparently had its origin from the portion of cyst wall which was left attached to the diaphragm at the time of lobectomy. The epithelialized portions of the empyema pocket were cauterized with silver nitrate and by electrocoagulation. The electrocoagulation was repeated five weeks later.

On September 12, 1938, the residual epithelial lining, especially in the costovertebral angle inferiorly and posteriorly and on the diaphragm, was excised, and a small plastic operation was performed to obliterate the remaining space. Microscopic examination of the excised tissue showed it to be covered by bronchial epithelium. The thoracic wound healed completely in two months. When the patient was last seen in May, 1939, he had no dyspnea or other pulmonary symptoms. His general health was excellent, and he was gaining weight. Roentgenograms of the chest showed only the changes resulting from the previous operative procedures.

Comment.—This infected bronchiogenic cyst had been treated for two years as an empyema. Biopsy at the time of the patient's admission indicated the correct diagnosis. Lobectomy was done, but difficulties were encountered later due to proliferation of the epithelium from a small portion of the cyst wall which could not be removed safely at the time of lobectomy. A portion of the empyema cavity remaining after lobectomy became lined with respiratory epithelium, and, thus, the pleural cavity did not obliterate spontaneously. Excision of the residual epithelium was necessary before complete healing occurred.

CASE 2.—C. B. (No. 495359), female, aged 5 years, was admitted July 7, 1937. The chief complaint was a draining sinus in the right side of the chest. The child had had measles, whooping cough, and chicken pox. Two years previous to admission, the patient developed pleurisy, and a diagnosis of empyema was made. At first, aspirations and intercostal drainage were employed; later open thoracotomy was performed. A sinus persisted and drained intermittently.

Physical examination revealed a fairly well-nourished and well-developed child who did not appear ill. There was a small sinus in the scar in the right part of the chest laterally. Marked dullness and distant breath sounds were noted over the right lower part of the chest anteriorly and laterally. Posteriorly the breath sounds came through clearly. Frontal roentgenograms of the chest showed a density obscuring the lower half of the right hemithorax. In the lateral projection the density was seen to be anterior and to have a rounded contour (Fig. 4). A clinical diagnosis of chronic encapsulated empyema was made.

On July 10, 1937, a thoracotomy was done, and the draining sinus was followed into the cavity which contained pus. The cavity was round and smooth-walled, but the significance of the smooth wall was not appreciated and a biopsy was inadvertently not obtained. No bronchial fistula was evident. A drainage tube was inserted, and a postoperative diagnosis of chronic empyema was made.

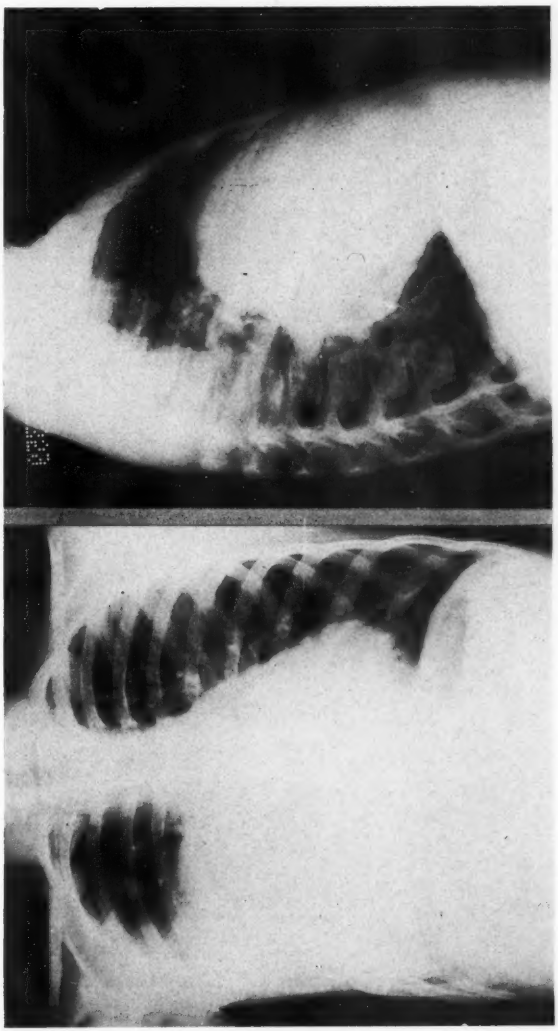

Fig. 4.—Case 2. July 7, 1937. Posteroanterior film showing large area of density in the right hemithorax. The lateral film demonstrates the rounded contour and the anterior location.

Following surgical drainage, the cavity decreased somewhat in size, as the pus within the cavity was under pressure before drainage. The rounded contour of the cavity persisted (Fig. 5). On August 19, 1937, the interior of the cavity was examined with the thoracoscope, as it was then suspected that the lesion might be

intrapulmonary. The walls of the cavity had a smooth appearance for the most part, and there was no bronchial fistula. A biopsy revealed only pyogenic granulation tissue, and a definite diagnosis of pulmonary cyst was not made at this time.

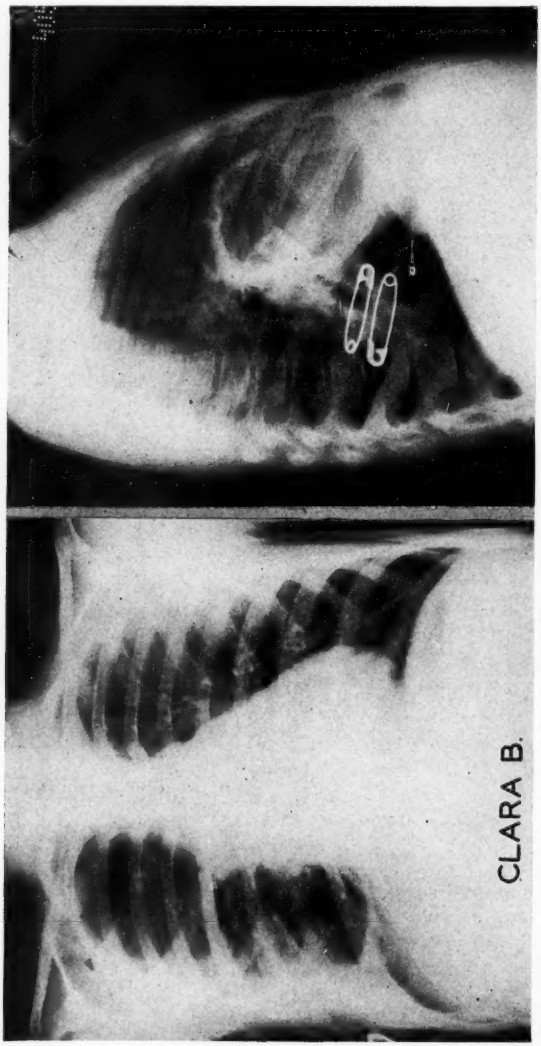

Fig. 5.—Case 2. Sept. 24, 1937. Roentgenograms ten weeks after drainage showing the persisting rounded cavity best seen on lateral film.

As the cavity continued to maintain a spherical shape and did not diminish in size as one would expect an empyema cavity without markedly thickened pleura to do, it seemed more and more certain that the cavity was intrapulmonary. On Oct. 1, 1937, a bronchogram showed distortion of the bronchial tree by the cystlike space in the region of the middle lobe, but no bronchial opening into the cyst was evident. No appreciable bronchiectasis was present.

In order to establish the diagnosis definitely, a more adequate biopsy of the tissue lining the cavity was necessary. The drainage site was enlarged, and it was then evident that the cavity wall could be separated readily from the thoracic wall. This finding established the diagnosis of an intrapulmonary cavity. Microscopic examination of several biopsies of the cavity wall showed a columnar epithelial lining and pulmonary tissue with chronic fibroid pneumonia and bronchiectasis.

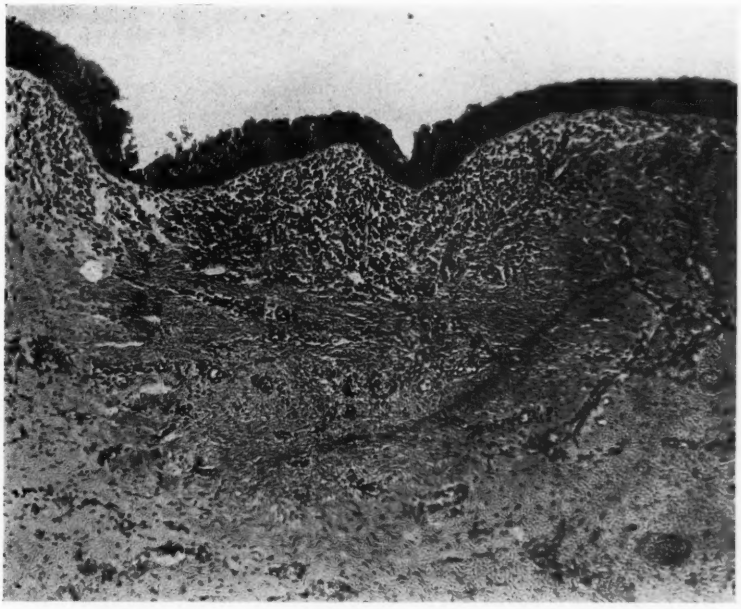

Fig. 6.—Case 2. Photomicrograph of cyst wall demonstrating columnar epithelium with underlying vascular connective tissue and lymphocytic infiltration.

On Nov. 20, 1937, excision of the pulmonary cyst was undertaken through an anterior approach. The outer wall of the cyst was attached to the adjacent structures by adhesions which were moderately firm, but relatively avascular, except in the region of the previous thoracotomies where they were dense and vascular. The adhesions between the cyst and the upper lobe were readily separable. No true hilar vascular structures or bronchus leading to the cyst could be identified. The hilar attachment of the cyst wall was very firm, and it was thought inadvisable to remove a very small portion of the cyst wall in this region because of the probable proximity of the artery to the right lower lobe. No appreciable bleeding occurred as the hilar end of the cyst wall was amputated. The small portion of epithelialized cyst wall which was not excised was thoroughly rubbed with 10 per cent formalin. The cyst wall for the most part measured only a few millimeters in thickness. A considerable part of the wall could not be recognized grossly as containing any pulmonary tissue. The cyst seemed to have replaced almost the entire middle lobe. The upper and lower lobes did not collapse during the operation because of the presence of adhesions. The wound through the thoracic

wall was closed loosely around a large drainage tube which was made airtight by the dressing around the tube. The patient's condition at the end of the operation was fair.

Microscopic examination of the cyst wall showed it to be covered by columnar epithelium of the respiratory type (Fig. 6), with areas of metaplasia to the stratified squamous type. Smooth muscle was present in the wall. Occasional mucous glands and groups of spaces lined by cubical epithelium were present in the connective tissue beneath the epithelium. In other areas there was pulmonary tissue showing chronic fibroid pneumonia.

Two weeks after operation the residual intrapleural space had a capacity of only 30 c.c., in contrast to the volume of the cyst which had been about 125 c.c. A sinus track remained for about three months and then healed spontaneously. When last seen in April, 1938, the patient was symptom-free and in excellent general health. The operative wound was well healed. A roentgenogram showed complete expansion of the lung and no evidence of the cyst. In June, 1939, the patient was reported to be without symptoms and in good health.

Roentgenograms were obtained later from the hospital where the patient was treated about two years before admission to the University Hospital. The first film shortly before the intercostal drainage operation showed complete obscuration of the right hemithorax, with moderate mediastinal displacement toward the opposite side; the findings were characteristic of a massive collection of fluid in the right side of the chest. Another film taken five weeks after the first drainage operation demonstrated drainage of the empyema, with re-expansion of the lungs, residual pleural thickening, and indefinite evidence of a shadow suggestive of a cyst. Films eight months before admission to the University Hospital showed the large cyst almost filled with fluid.

Comment.—This patient appears to have had drainage of an actual empyema at a first operation elsewhere. A roentgenogram made five weeks later presents suspicious, but indefinite, evidence of an air-filled pulmonary cyst in addition to the drained empyema. Subsequent films show a fluid-filled cavity which was later proved to be a pulmonary cyst. Enucleation of the cyst was undertaken successfully, with subsequent complete healing. Although the early roentgenograms cast some doubt upon the congenital nature of the cyst, we believe the histologic evidence favors the diagnosis of a congenital lesion.

CASE 3.—L. M. (No. 380762), male, aged 12 years, was admitted April 27, 1936. The chief complaint was cough and loss of weight. In early childhood he had had measles and frequent attacks of bronchitis, and at 6 years of age he had pneumonia. A chronic cough persisted, but the patient was otherwise well until six weeks before admission. The cough became worse and was accompanied by malaise, fever, weight loss, and pain in the left side of the chest. The patient coughed considerably, except when lying on the left side. One week before admission he had pulmonary hemorrhage, and following this he coughed up a large amount of brownish, foul-smelling sputum.

Physical examination revealed an undernourished, poorly developed, pale, acutely ill child. There was a definite lag in the respiratory excursion of the left side of the chest, but the contour of the chest was fairly symmetrical. The trachea was markedly deviated to the right, and the cardiac impulse was seen to the right of the sternum. Dullness and absent breath sounds were noted over the entire

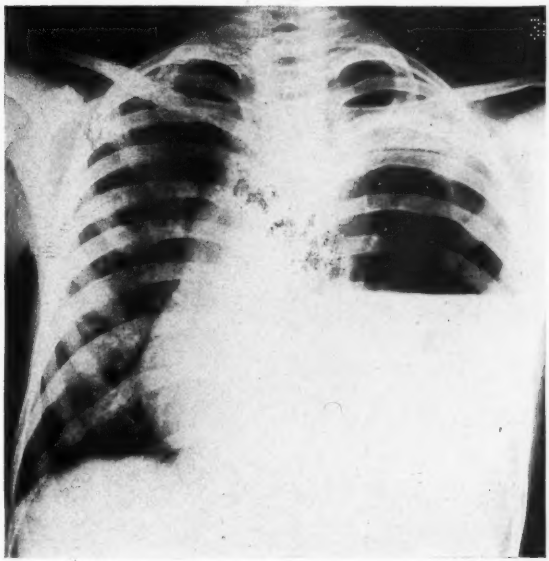

Fig. 7.—Case 3. April 27, 1936. Roentgenogram showing large accumulation of air and fluid in the left hemithorax, with mediastinal displacement to the right. The upper portion of the left hemithorax is occupied by lung.

Fig. 8.—Case 3. April 27, 1936. Roentgenogram after aspiration of fluid showing strands of tissue extending downward and outward from the left hilum.

left side of the chest. The right lung was clear. A diagnosis of tension pyopneumothorax with bronchopleural fistula was made.

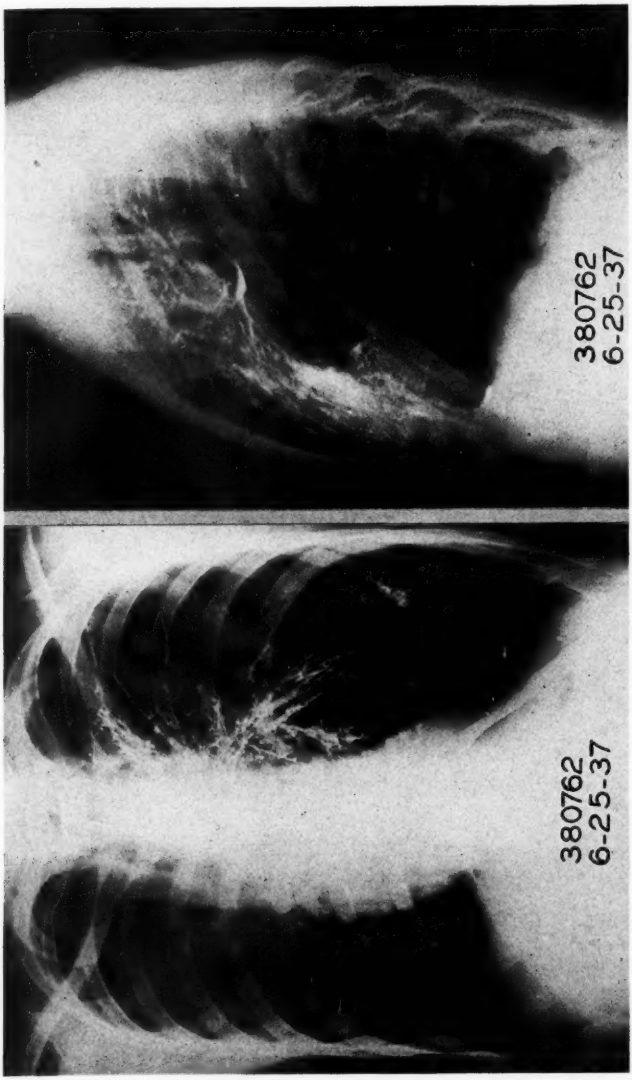

Fig. 9.—Case 3. June 25, 1937. Bronchogram made fourteen months after drainage of the cavity and subsequent to the attempted muscle plastic closure of fistulas shows no evidence of bronchiectasis. The frontal film demonstrates the absence of pleural reaction and scoliosis, and the persistence of mediastinal deviation and depression of the diaphragm. Marked forward displacement of the bronchi by the cyst is seen on the lateral film.

A roentgenogram of the chest showed a large fluid accumulation with overlying air in the left hemithorax (Fig. 7). Aerated lung occupied the apical portion of the left side of the thorax. The mediastinum was displaced considerably toward the right.

Thoracentesis yielded 1,000 c.c. of brown, foul pus, which showed gram-positive cocci and bacilli on smear. The following day a thoracotomy was performed. A

segment of the tenth rib was resected, and the parietal pleura was seen to be only slightly thickened. A large quantity of thin pus and air was evacuated. As the patient's condition during the operation was poor, a drainage tube was quickly inserted, and no biopsy was obtained.

Following drainage the cavity did not decrease as much in size as one would expect with an empyema. On July 2, 1936, a temporary left phrenic nerve interruption was performed in order to lessen the size of the cavity, but there was no appreciable elevation of the diaphragm. Four weeks later a pedicle muscle flap was applied over the large bronchial fistula, and an attempt was made also to close the other fistulas. The muscleplasty was unsuccessful. Five weeks later a sudden rise in temperature occurred, and a blood culture at this time was positive for hemolytic streptococcus. Transfusions and serum were given. An abscess which developed on the dorsum of the hand was incised and drained. The patient improved and was discharged two months later.

Fig. 10.—Case 3. Nov. 9, 1937. The large cavity (indicated by arrows) still persists following thoracoplasty which was done under the presumed diagnosis of empyema. The positions of the mediastinum and diaphragm remain the same as before thoracoplasty.

He was readmitted in March, 1937, at which time a large intrathoracic cavity still remained. The mediastinum continued to be displaced to the right. Roentgenographic studies with the patient in various positions demonstrated that the failure of the mediastinum to return to its normal position could not be due to fixation of the mediastinum, for there was a further shift of the heart and mediastinum toward the right side when the patient was in a right lateral recumbent position. On March 20, 1937, another attempt was made to close the bronchial fistulas, as it was believed that the fistulas hindered re-expansion of the lung. This attempt was also unsuccessful. (Fig. 9.)

The patient was again admitted on Aug. 1, 1937. A four-stage extrapleural thoracoplasty was performed as the condition was still thought to be a chronic

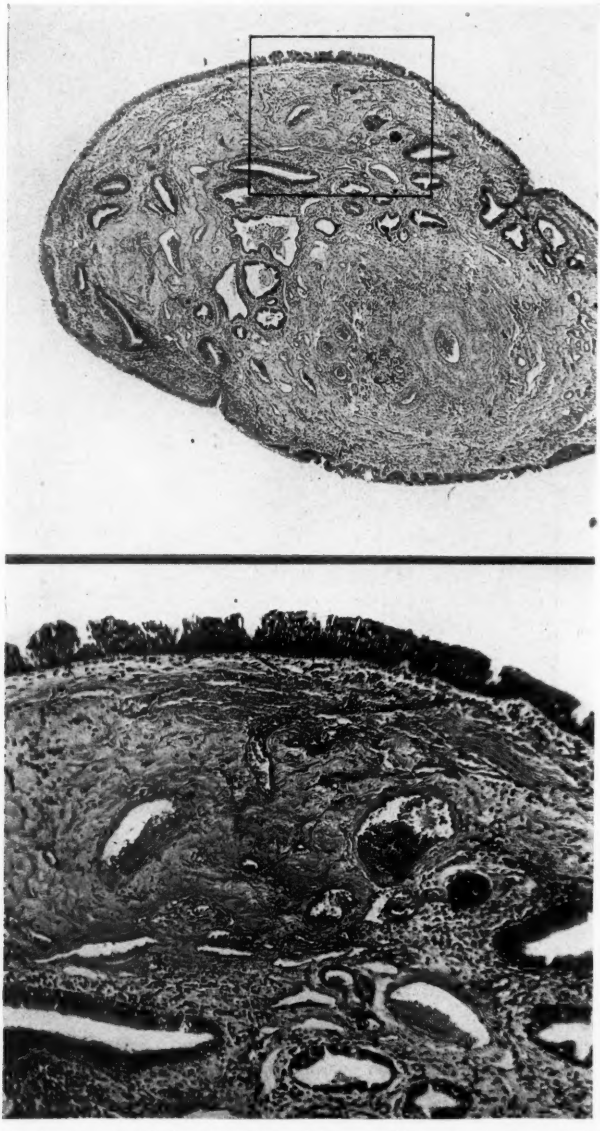

Fig. 11.—Case 3. *A*, Photomicrograph of cross section of a strand of tissue seen traversing the cavity in Fig. 8. Ciliated respiratory epithelium surrounds this tissue which contains bronchi and blood vessels. *B*, High power magnification of *A*.

empyema. A body cast was applied between stages to lessen the degree of resultant scoliosis. A large uncollapsed cavity (Fig. 10) still remained after the thoraco-

plasty. At this time the diagnosis of pulmonary cyst was first suspected, and a strand of tissue which traversed the cavity was biopsied. Microscopic study showed that this strand was covered by stratified columnar epithelium and that it contained bronchi and blood vessels (Fig. 11). This finding indicated the intrapulmonary nature of the persistent cavity.

Since the true nature of the cavity had now been demonstrated, and since collapse of the thoracic wall had failed to close the cavity, it was felt that lobectomy was indicated. On July 18, 1938, Dr. John Alexander removed the left lower lobe containing the cyst. A good interpleural cleavage plane was found; the lower lobe was freed readily from the parietal pleura, and a small pedicle was developed. The densest adhesions were on the dome of the diaphragm, under the regenerated ribs, and over the pericardium. The apex of the lower lobe was adherent to the mediastinum. The interlobar fissure did not contain dense adhesions, and the upper lobe appeared normal. The lower lobe was amputated distal to a tourniquet, but a 2 cm. area of cyst wall which extended into the hilum was left in situ; this was rubbed with 10 per cent formalin and then closed over with mattress sutures. The patient's condition at the end of the operation was fairly good. The residual cavity diminished rapidly in size after removal of the cyst. Six weeks later only a small sinus track remained, and the wound was healed completely several weeks later. In May, 1939, the patient had no cough or expectoration, and his general condition was good. He was still in a body cast because of the scoliosis which followed the thoracoplasty.

Comment.—This pulmonary cyst was diagnosed incorrectly as a chronic empyema with bronchopleural fistula. The persistent contralateral displacement of the mediastinum, the depression of the diaphragm, the absence of thickened pleura, and the absence of scoliosis would be unusual in a chronic empyema and should have suggested the correct diagnosis. Earlier biopsy of the strands of tissue traversing the cavity would have indicated its intrapulmonary nature. A total thoracoplasty with its resultant deformity in a child of this age would then have been avoided.

SUMMARY

Large infected solitary pulmonary cysts lined with epithelium are often confused with encapsulated empyemas. Three cases which illustrate this differential diagnostic problem are presented. The pathologic aspects of epithelialized pulmonary cysts, in so far as they pertain to diagnosis and treatment, are discussed, and the indications for radical surgery are presented.

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DISCUSSION

DR. LEO ELOESSER, SAN FRANCISCO.—There is a great deal of confusion in literature as to what constitutes a cyst. I think we had better confine ourselves, for the purpose of this present discussion, to those cysts that Dr. Maier described as the epithelial congenital cysts of the lung. The differential diagnosis is extremely important, and I am very glad to hear what Dr. Maier had to say. I am sure that all of you, or many of you, in your hospitals now have patients with cysts that are existing under the name of refractory empyemas that will not close. It has happened to me, although I have been particularly interested in lung cysts and have been on the lookout for them, and, as you see, it has even happened at Ann Arbor.

You will remember in Sauerbruch's book that he describes four cysts, two of which were operated upon under a mistaken diagnosis of empyema. The diagnosis is very difficult. As Dr. Maier brought out, it is a microscopic diagnosis, and whether or not you have a thin membrane that contains a few elastic fibers, determines whether you have an empyema or cyst with which to deal. A few practical points in diagnosis, I think, will be of help. The contents of these cysts, if they are infected, very often contain nothing but staphylococci. That is rare in empyema. In the second place, the secretion from these cysts is peculiarly mucoid and different from empyema pus.

As to treatment, I am glad to see that Dr. Maier advocates treatment in two stages, although Dr. Harrington has shown what brilliant results one can achieve with a one-stage operation. It is simpler for most of us who are not equipped with his great apparatus and his excellent organization to operate in two stages. The cysts can be extirpated in the way described by Sauerbruch's assistant, Lebsche, once they have been opened by following up the cyst to the pedicle; or, as is usually simpler, one can remove the whole lobe that contains the cyst.

The upper lobe cysts are ordinarily symptomless and I think they can be left. Really, a cyst is not a disease; it is a condition and it is only when it becomes infected that it becomes a disease. Upper lobe cysts are often nothing more than a large pneumothorax or air bubble in the top of the chest and ordinarily drain themselves through a bronchus. The most troublesome symptom of upper lobe cysts may be their sudden expansion or ballooning up by a valve action. This may occasion great respiratory distress. Permit me to show just a few pictures of cysts that both we and others have made some mistakes in. They will supplement what Dr. Maier has shown.

(Slide) Here is a film of a boy who had a cyst. Drainage and operation had been performed before he came to me, and it took me a long time before I recognized that this was a cyst. Nothing happened to it. As you see, it is a round cantaloupe in the bottom of his chest, with a fluid level. We removed the cyst, and the boy recovered.

(Slide) This is also a cyst that was drained elsewhere, a cyst that contained two compartments, a very large upper compartment like a pneumothorax and a lower multilocular one.

(Slides) This is another cyst. This had also been drained elsewhere. This is the cyst after its extirpation by lobectomy; this is another view of the cyst cut open.

(Slide) This boy had a lower cystic lobe removed and was perfectly well, except for a bronchial fistula. He was operated upon for closure of the fistula and died of air embolism.

(Slide) Another boy with a large, rounded shadow in the lower chest. This has been drained and the shadow is smaller.

(Slide) This woman had a shadow in the chest wall which was very like a cyst at times. In this particular picture you see it against the chest wall. When it was fuller, it assumed a round form which was quite indistinguishable from a cyst. It was a localized tuberculous empyema.

I think that the chief value of Dr. Maier's paper lies in his emphasis upon the difficulty of an accurate differential diagnosis between a cyst and empyema.

DR. JEROME R. HEAD, CHICAGO.—I would like to ask Dr. Maier concerning the temperature in these cases. It has been my experience that pus in epithelial-lined cavities in the chest does not cause fever. In several cases of this kind, where the differential diagnosis lay between empyema and cyst, the latter diagnosis has been made correctly because the patient was absolutely symptomless except for a productive cough. Another clinical symptom of cysts of the lung is hemoptysis. This practically never occurs in empyema.

DR. J. J. SINGER, LOS ANGELES.—We have used a method that is almost 100 per cent in differentiating empyemas from the cysts, whether they are infected or not. That is by the introduction of iodized oil directly into the cavity, turning the patient around, front, back, sideways and even upside down; one can delineate the cavity in its entirety, and these strands that were mentioned by Dr. Maier are outlined beautifully. We have been considering these strands, even without the microscopic evidence of lung tissue, as a pathopneumonic condition of cysts.

There is one other question that relates to this subject and that is the thing that Dr. Eloesser spoke about, the symptomless cysts—whether or not they should be operated upon. Unfortunately or fortunately, these patients do not come to a doctor for examination because they have no complaints. It is only when something happens that they come; we have had numerous patients in whom the cysts have ruptured into the pleural cavity and who then have symptoms of a large pneumothorax.

In one case, in order to determine the difference between the cyst cavity and the pleural cavity, we inserted a needle connected with a manometer, and we found a negative pressure. We knew then that we were in the limits of a space that was probably bound by the two pleurae. Then we introduced the needle still farther into the cavity, and we found a +6 and −6, or a +8 or −8—in other words, a cyst that must be connected with the main bronchus. In the last three or four years we have seen a great many of these cases reported, and we all know that many that we did have under the diagnosis of empyema have been such cases.

DR. CAMERON HAIGHT.—I would like to make a brief remark concerning terminology. It is readily apparent in reviewing the literature that the term "congenital cystic disease of the lung" has at times been indiscriminately used to include the acquired cysts. We believe that a definite distinction should be made, if possible, between congenital and acquired cysts because the pathologic aspects and treatment of the two types are usually different. In cases in which we have had normal x-rays of the chest before the development of a tension cyst, there has been a great tendency for the cyst to heal spontaneously. We also have had cysts in which the first x-ray showed, in our opinion, a pneumonic process, not a cyst filled with fluid. The lesion has progressed to the positive pressure type of cyst

which, in turn, has healed spontaneously. We wish merely to make the distinction between the cysts which we can be certain are of the acquired nature (we cannot always be certain) and the type that is lined with epithelium.

DR. HERBERT C. MAIER.—Dr. Eloesser commented concerning the organisms present in these cysts. Two of our patients had been operated upon previously so we cannot discuss their bacteriologic findings. In the third case foul pus was present; this may have been due to a secondary infection through the bronchial tree. The two cases that had been draining for two years both had thin pus. It was almost watery in character, as Dr. Eloesser has mentioned. The cultures, however, showed mixed organisms, as one would expect in view of the previous drainage.

In regard to the upper lobe cysts, I certainly agree that many of them give no symptoms, and I feel that a considerable number are acquired cysts, secondary to infection. I believe that, out of the total number of cystlike spaces in the upper lobe that are seen, only a small number are epithelialized, and, therefore, the problem of treatment is rather different. There is a good possibility of the non-epithelialized cyst disappearing spontaneously.

In answer to Dr. Head's comments, I can say that both of the cases which had previously been drained for a two-year period showed no evidence of systemic effect from prolonged infection. They were in good condition. The third case was febrile and acutely ill at the time of admission, but I believe that the reaction may be explained by the foul infection in the cyst. The same patient had a history of hemoptysis of as much as one-half cup of blood at one time. I feel that hemoptysis is a definite point in differential diagnosis of cyst and empyema.

I agree with Dr. Singer that those strands of tissue seen on the roentgenogram could hardly be anything other than strands within a cyst, although they were not recognized as such at that time.

I would again like to emphasize the fact that I do not recommend radical therapy for the majority of cysts. I am limiting the indications outlined here purely to the group with infection and an epithelialized cavity which will not obliterate.

I wish to thank the discussers for their interesting comments.

JOINT MANIFESTATIONS ASSOCIATED WITH INTRATHORACIC TUMORS

WILLARD VAN HAZEL, M.D.
CHICAGO, ILL.

JOINT manifestations may constitute the initial complaint in intrathoracic tumors. Clubbing of the fingers in bronchiectasis, chronic lung abscess, or heart disease is common and shows itself usually in the presence of symptoms which suggest the likely diagnosis. However, less common are the joint manifestations of hypertrophic pulmonary osteoarthropathy which, when occurring rapidly as a primary complaint, can easily be mistaken for arthritis. Its chief symptoms are clubbing of the fingers, with swelling, pain, tenderness, and, in some cases, an accompanying elevation of temperature probably due to the primary disease. There appears to be an intimate relation between simple clubbing of the fingers and toes and osteoarthropathy; this will be referred to later.

When Graham first accomplished successfully a pneumonectomy for carcinoma, it immediately confronted us with the same problem of carcinoma elsewhere in the body, namely, early diagnosis, if surgery were to have its best chance to achieve what it could. Churchill, in a study of a group of cases, has shown the low percentage of operability in bronchiogenic carcinoma. The varied onset in this disease, with its tendency to simulate other conditions, has made this a problem, unless carcinoma is considered in the differential diagnosis in all cases, and even then proof of its existence may be difficult.

Early diagnosis is not served by the inclusion of symptoms and signs such as emaciation, multiple lung abscesses, tumor cells in pleuritic fluid, or biopsy of metastatic lesions. It seems worth while then, in a symposium on lung tumors, to record seven cases in which the initial symptom was joint changes. In five cases, malignancy was proved, and in two a benign tumor was present. There was a complete absence of symptoms referable to the chest from one month to one year after the onset of joint symptoms. In a case of bronchiogenic carcinoma, a pneumonectomy was followed by an immediate disappearance of all "arthritic" symptoms in a patient who had been bedridden and helpless for six months because of painful joints. In another patient the removal of a large fibroma of the right lower chest likewise was followed by a prompt disappearance of similar symptoms which had confined her to

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From the Department of Surgery, University of Illinois College of Medicine, and St. Luke's Hospital, Chicago.

bed for five months. This rather convincing evidence of the relation of these tumors to the osteoarthropathy present prompted the collection of these cases.

The symptoms and signs were those of hypertrophic pulmonary osteoarthropathy. The onset of the joint involvement in these cases was either a stiffness or swelling accompanied by some pain. In three patients it was abrupt, and in four, gradual. Although clubbing was present in all, this was overshadowed by the swelling, pain, and disability. Six were treated for arthritis, and none gained relief. In four the affection was sufficiently severe to confine them to bed, and in none of these cases were the chest symptoms annoying, except during hemoptysis in one patient with bronchiogenic carcinoma. The fingers and hands were enlarged, giving the appearance of swelling without a pitting edema, and dusky cyanosis was observed, which was marked in three patients. The swelling and color were comparable to those seen about the head and neck in superior vena cava obstruction. The skin of the hands was usually moist; flexion of the fingers caused varying degrees of pain. The bones showed the typical periosteal proliferation, particularly of the ulna, radius, tibia, and fibula, and, in some, of the metacarpal and metatarsal bones. Two patients had remissions in their symptoms for a period of time. The temperatures varied from 99 to 101° F., suggesting an infection as a possible cause of the joint symptoms, but only Case 7 had an abscess of the lung complicating the tumor. The patient with the benign fibroma had elevation of temperature up to 101° during exacerbations of the joint symptoms, but no infection at operation or following it was in evidence.

TABLE I

INTERVAL BETWEEN JOINT AND CHEST SYMPTOMS

NAME	INTERVAL BETWEEN JOINT AND CHEST SYMPTOMS	INTERVAL BETWEEN ONSET OF SYMPTOMS AND DIAGNOSIS OF CHEST TUMOR	PATHOLOGY
I. E.	12 mo.	18 mo.	Bronchiogenic carcinoma
S. H.	8 mo.	6 mo.	Bronchiogenic carcinoma
M. K.	2 mo.	5 mo.	Bronchiogenic carcinoma
V. K.	1 mo.	6 mo.	Fibroma
A. G.	9 mo.	7 mo.	Metastatic sarcoma
S. A.	No chest symptom	1 mo.	Dermoid (?)
G. H.	3 mo.	7 mo.	Bronchiogenic carcinoma

Castillo and Lopez and Sala each reported a case of pulmonary carcinoma beginning with osteoarthropathy. Two years ago, Craig reported four cases of pulmonary neoplasm in which the first symptom likewise was osteoarthropathy. Three of the four patients had been treated for rheumatism. The intervals between the onset of the joint symptoms and the symptoms of intrathoracic disease were three months, seven months, seven months, and eight months.

Keller and Callender removed a neurofibroma attached to the pericardial pleura in a Filipino whose chief symptoms were stiffness and swelling in the joints, and they observed the improvement in the latter following the operation. Nef reports a toxic periostitis associated with osteoarthropathy which disappeared after the removal of a benign tumor of the lung.

CASE 1.—I. E., housewife, 46 years of age, was seen in December, 1927. She first noted swelling of the ankles and lumbar pain two years before. This disappeared after one month, to recur again one year later. At this time, however, she had a dry cough which became productive four months later; this cough was the only symptom attributable to the chest throughout her illness. She noted a clubbing of the fingers, along with swelling of the hands, ankles, and knees, and there was a steadily increasing pain on motion. No relief had been afforded by various treatments, including an operation. She was seen for the first time two years after the initial swelling, and a diagnosis of chest tumor was made. The temperature ranged from 99 to 101° F. There was marked cyanosis of the finger tips and a dusky cyanosis of the hands and feet, and both showed definite enlargement but no pitting edema. Motion of the fingers, wrists, knees, and ankles was extremely slow and caused severe pain. X-ray examination revealed a homogenous shadow of the upper left lobe which proved to be a tumor at exploratory operation, and radon seeds were inserted. Microscopic section revealed a primary carcinoma of the lung. The patient remained bedridden and helpless, with ever increasing pain in the affected joints, and opiates afforded the only relief.

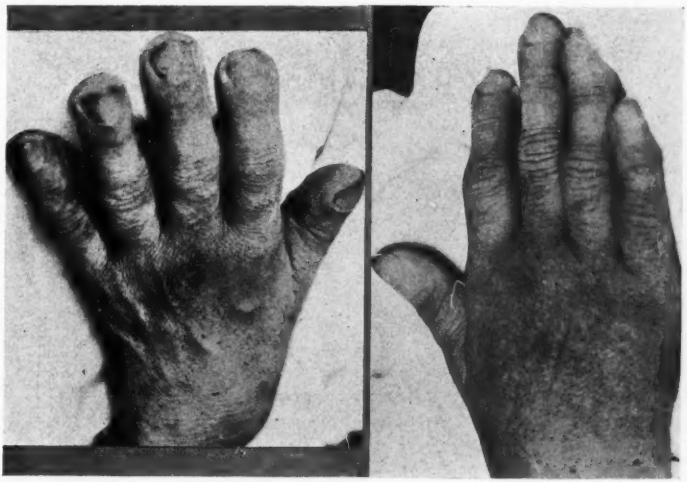

Fig. 1.—Case 2. Photograph of hands. The clubbing is evident, as well as the thickening due to swelling which failed to pit on pressure.

CASE 2.—S. H., aged 52 years, noted painful and swollen ankles which failed to respond to any treatment. Within six months her knees and hips were similarly affected, at which time she entered a hospital for a general examination and it was found that she had a chest tumor. Since this time she has been confined to her bed

because of painful joints. Eight months after the onset of her symptoms she began to feel pressure in her chest, attended with more difficult breathing, and this was followed by increased swelling and pain in the fingers, wrists, elbows, shoulder, knees, and feet. Clubbing of the fingers and toes was marked. The hands and forearms were enlarged, and a dusky tinge was present in the hands. There was no pitting in the swollen parts. Biopsy through an intercostal incision showed primary carcinoma of the lung. Roentgenograms of the upper and lower extremities showed proliferative periostitis typical of pulmonary osteoarthropathy.

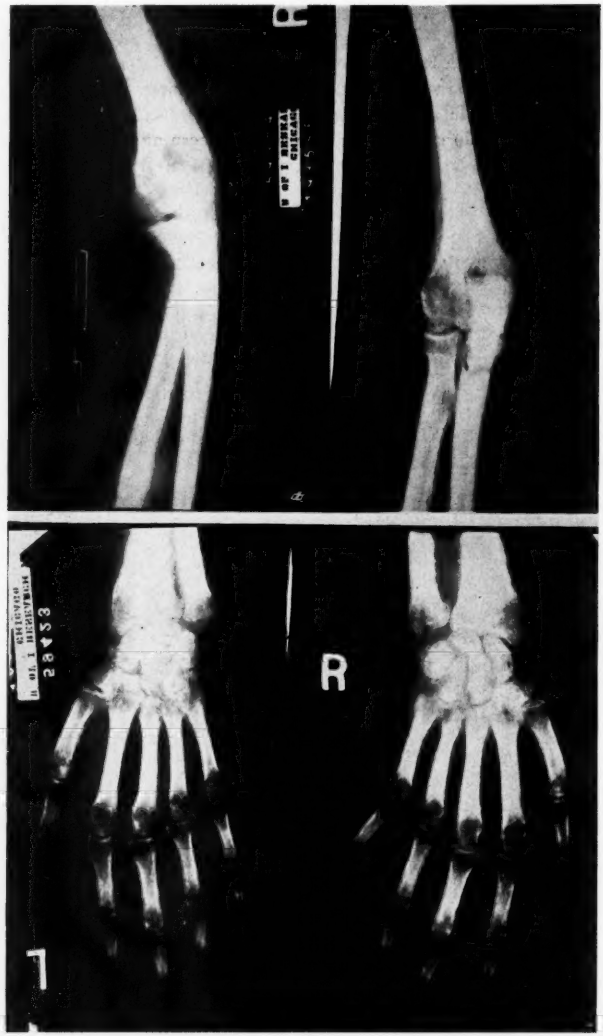

Fig. 2.—Case 3. Roentgenograms of the elbows and hands, showing periosteal proliferation along the humerus, radius, and ulna, and also the metacarpal bones.

CASE 3.—M. K., a 40-year-old housewife, began to have swelling, stiffness, and pain in her hands, wrists, feet, and ankles in April, 1935, following the extraction of some teeth. Previous to this she had enjoyed excellent health. A month later her right arm was so stiff that she could not move it, and only with extreme difficulty could she move her knees. No treatment had brought her any relief. Two months after the onset she had blood-tinged sputum for several days, and then, on five occasions, massive hemorrhage of about one teacupful of blood. Subsequently there developed a burning sensation and heavy feeling in the chest, with an occasional cough. She entered the hospital five months after the primary symptoms appeared. The patient was bedridden from the onset of joint symptoms, and her chief complaint was painful, swollen joints, but there was no pitting on pressure. There

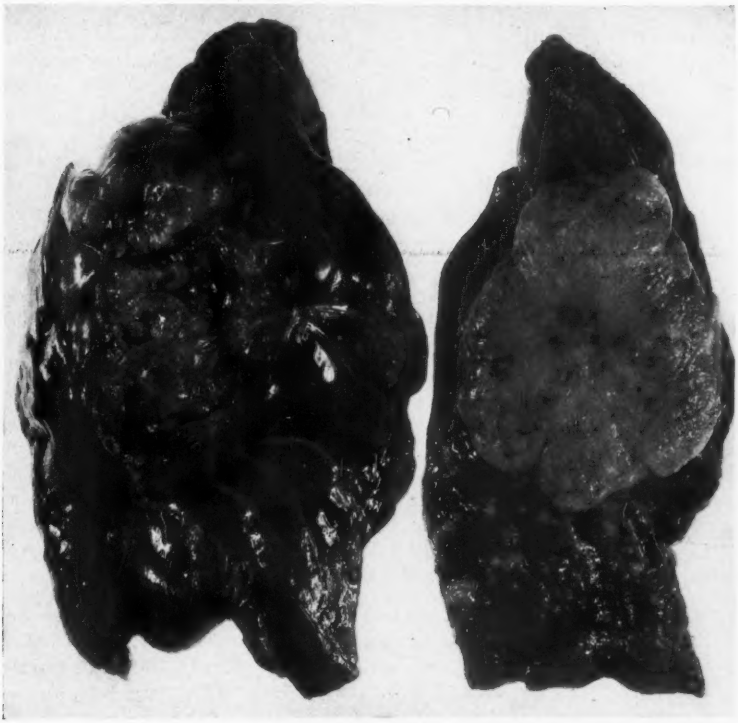

Fig. 3.—Case 3. Photograph of the lung following pneumonectomy. The hilar area and the tumor mass in the sectioned lung are shown.

were clubbing of the fingers, a dusky cyanosis, a moist skin, and extreme pain on motion. She was entirely helpless and had to be fed. X-ray examination showed periosteal new bone formation involving the humerus, ulna, radius, tibia, fibula, metacarpals, and metatarsals, typical of the bone changes seen in hypertrophic osteoarthropathy. Diagnostic pneumothorax showed a mass with apical adhesions in the upper left lobe. Pneumonectomy was performed, with the removal of carcinomatous hilus glands. The day following the operation the joints had lost their swelling, cyanosis, and stiffness, as well as pain on motion. To the patient the most remarkable feature was indicated by her first words, "Look, I can move my knees up and

down now; it took me fifteen minutes to do this before.'' After six months' duration, the joint symptoms had disappeared dramatically overnight. Clubbing, however, diminished gradually. Three months after operation the bones showed no improvement; in fact, there seemed to be some increase in bone formation, which occurs sometimes, Locke pointed out, although the other signs and even the primary disease may disappear. However, there was no recurrence of joint symptoms at any time.

CASE 4.—V. K., a 32-year-old stenographer, noted in July, 1937, that her hands were stiff, making typing difficult. Her fingers also seemed larger, and within a month her ankles, knees, wrists, and hands were swollen and painful. While bending over to lace her shoes, she had a stabbing pain in her right chest which recurred at varying intervals. An x-ray film showed an opacity in the lower right chest which was interpreted as pleurisy. She was confined to bed because of her disability and treated for arthritis. The joint condition would subside periodically, only to recur. She was admitted to the hospital seven months after the onset, having been confined to bed throughout the last five months. Although the patient was first seen during a remission in the joint manifestations, there were typical hippocratic fingers, swelling, dusky cyanosis, moist skin, and tenderness on motion in the hands, wrists, ankles, and knees. During exacerbations, sweating was more marked, and temperature up to 101° accompanied the increased symptoms. No therapy had brought any relief.

The tumor was clearly demarcated on the x-ray film, and the lateral view showed it to lie anteriorly. The tentative diagnosis was dermoid. At operation a large, solid tumor about the size of a large grapefruit was encountered. It had three cordlike attachments to the pericardium which were vascular and readily ligated. The origin of the tumor was the interlobar pleura at a point close to the hilum where the fissures of the three lobes merge. The tumor was a fibroma and weighed 610 Gm. It is conceivable that, because of its location, size, and weight, it could exert pressure on the pulmonary vein, thereby altering oxygenation of blood coming from the right lung. The pain, swelling, and cyanosis disappeared the day of the operation, and the disability, aside from some stiffness caused by disuse, and the clubbing disappeared during the first few postoperative days. There has been no return of joint symptoms, and the clubbing has disappeared almost entirely. There were demonstrable bone changes in the ulna and radius of this patient, but not in the lower extremities.

CASE 5.—A. G., 74 years of age, was first operated upon in 1914 for a fibrosarcoma of the abdominal wall, this type of tumor sometimes being designated desmoid. She again had surgical removal for tumor recurrences in 1922 and 1931. She entered St. Luke's Hospital, under the care of Dr. Howard Wakefield, in July, 1938, because of recurrence. He had observed a clubbing of the fingers during her dispensary visits since March, when she complained that her elbows, knees, and ankles were painful. It was noted at this time that her elbows, hands, and legs were stiff, that the hands were swollen, and that the clubbing was more marked. She returned to the hospital in October, 1938, complaining of fatigue and weakness and ''arthritic'' pains in both extremities. The clubbing and thickening had increased. There was a cyanotic tinge to her hands since her joints had become stiff. X-ray examination revealed a mass in the left lower chest the size of an orange and another in the right upper lobe the size of a walnut. In December she was readmitted to the hospital because she began to cough and to have a sensation of pressure in her chest. She died in March, 1939. The essential findings at autopsy were metastatic fibrosarcoma of the right upper lobe, tumor obstruction of the left main bronchus and left pulmonary

vein, chronic passive hyperemia and edema of the left lung, and hypertrophic pulmonary osteoarthropathy of the hands. A drawing by E. F. Hirsch showing the protrusion of the tumor into the pulmonary vein was made from the fresh specimen.

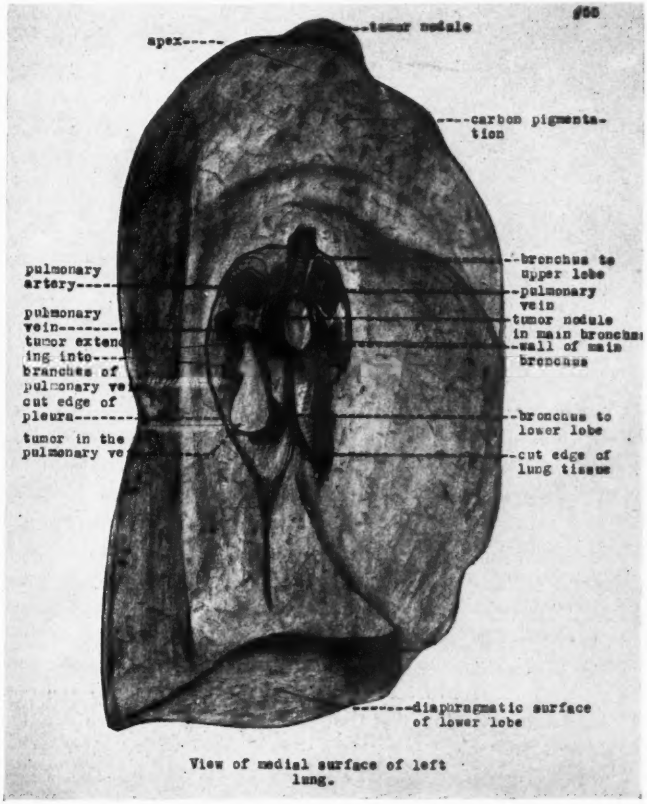

Fig. 4.—Case 5. Drawing of the removed lung at autopsy. The tumor mass is shown in the bronchus, as well as the pulmonary vein.

Case 6.—S. A., the wife of a physician, had a routine examination in seeking a possible cause for her "arthritis." An x-ray film revealed an anterior mediastinal mass which is known to have been present now for eight years. This patient has not been seen by the author, but the husband's description of the joints coincides with the typical hypertrophic pulmonary osteoarthropathy. There has been no relief afforded by varied treatments during the eight years, although remissions characteristic of the condition occur from time to time.

Case 7.—G. H., 62-year-old female, had influenza in March, 1937. She remained weak during the summer. She noted a change in the shape of her fingernails and some stiffness in her hands, which were definitely larger than formerly. In October, 1937, she had a severe coughing spell, with hemoptysis followed by a chill and fever. Cough with purulent sputum and signs of abscess led to bronchoscopic section, which

showed carcinoma. The abscesses were drained as a palliative procedure. No bone changes were demonstrated in this case.

Following the independent description of hypertrophic pulmonary osteoarthropathy by Bamberger and Marie, by whose combined names the disease is often called, many case reports followed. Packard, Field, and others wrote on acromegaly and osteoarthropathy, the close similarity in gross appearance in some instances being striking. To show the distinct entity of the condition caused Marie, in 1890, to differentiate it from acromegaly, which he had described four years earlier.

Locke was able to collect 144 reported cases in 1915, including five of his own. Of this number, the respiratory tract was the site of the primary disease in 108, and in this group, tumors of the mediastinum, pleura, or lung occurred in nine patients. X-ray studies of his cases over a period of five years led him to conclude that the subperiosteal proliferation loosely attached to the shaft in the early stages might later become fused, compact bone; that the proliferation in advanced cases might become generalized; that late changes might include erosion of cartilage, lipping about the joint, and, in some instances, ankylosis; and that exacerbations of the primary disease caused simultaneous increased swelling, pain, and tenderness in the joints and increased activity in the bone, while remissions occurred with a subsiding primary process. In order that he might determine more fully the disputed relationship between simple clubbing of the fingers and hypertrophic pulmonary osteoarthropathy, roentgenograms of the extremities were made of thirty-nine patients exhibiting the former; in twelve, the long bones showed periosteal proliferation identical with that seen in Bamberger-Marie's disease. The two conditions, from this work and the observations of others, appear to show that osteoarthropathy is an exaggerated form of simple clubbing. In Case 5, Wakefield observed this progressive process, beginning with the stiffness and clubbing which gradually increased and later the enlargement of the hands, which led to the x-ray film showing the metastatic nodules in the lungs, although no chest symptoms occurred until two months later.

Unsuccessful attempts have been made to create this condition in experimental work. Toxins in the form of bronchiectatic secretions were injected in animals by Bamberger shortly after his description of the disease, but they failed to produce any bone changes. Phemister also injected cultures of various organisms without obtaining periostitis. Because most of the earlier cases were associated with suppurative diseases, it seemed possible that a toxin could be elaborated which would give rise to this process. However, in tumors infections may play no part at all, and yet degeneration of tissue may occur and render some degree of toxicity. Only in Case 7 was infection present soon after the onset, and in this patient the osteoarthropathy was the least marked of

the group. Stephens, agreeing with most observers that peripheral blood stasis was the likely factor in producing osteoarthropathy, was unable to induce bone changes in animals. Compere and Adams sought to produce similar effects by creating intrathoracic complications in dogs, simulating disease comparable to that in which the condition is likely to be found. Pressure through paraffin injection in the pleural cavity, empyema and chronic abscess, and stenosis of the bronchus rendering large proportions of pulmonary tissue unaerated all failed to reflect themselves in a permanently altered blood chemistry. These authors added, however, that no sustained dyspnea or cyanosis had been accomplished. Their two patients showed dyspnea and cyanosis and an increased carbon dioxide content of the serum, although these readings were taken only a few days preceding death.

Campbell had an opportunity to secure a finger during life which showed marked clubbing. In his study of this specimen, he found the enlargement was due to edema which separated the connective tissue fibers, and that the greatest thickening occurred between the bone and the nail bed. He was unable to demonstrate increased fat or fibrous tissue thickening, although he grants that an edema of long standing could easily lead to the latter. He admits the absence of pitting, the usual sign of edema, but cites Widal's observations that the tissues are capable of taking up considerable amounts of water before the clinical sign of pitting manifests itself. The prompt disappearance of swelling, cyanosis, pain, and disability in our cases following the removal of the tumor seems to lend support to this belief. It is difficult to conceive of anything, except what the improved circulation could carry away, as capable of bringing about this abrupt change. Neither of the patients was administered oxygen following the operation.

Campbell convincingly postulates that transference of oxygen from the blood is dependent upon the oxygen tension in the blood being less effective where the circulation is slow, as it is in the hands, feet, and nose. This decrease in oxygen tension is brought about by faulty aeration of blood which passes through the lung. He further states that this anoxemia, which varies in degree, leads to edema where the circulation is slow, namely, in the extremities. In the cases reported here, the dusky cyanosis was most marked in the patients who showed the greatest amount of swelling, pain, tenderness, and disability, suggesting that cyanosis, if it be the causative factor in producing edema, does so in proportion to its degree. Of the varying conditions now reported producing osteoarthropathy, most of them do not show an obstruction to venous return, but rather, as Campbell states, "a varying amount of lung tissue has ceased to fulfil its proper function." In Locke's 144 collected cases, 20 per cent occurred in association with pulmonary tuberculosis. Fishberg found that, whenever clubbing of the fingers occurred in phthisis, the patient had dyspnea and cyanosis.

Campbell, Sacasa, and Camp recently reported a case of osteoarthropathy in which no intrathoracic or other pathology was found. Both the venous and arterial oxygen tensions were within normal limits.

Only a small percentage of intrathoracic tumors are associated with osteoarthropathy. However, this may be explained by the fact that only when chronic anoxemia exists are these changes likely to appear, and this, in turn, may be governed by the location of the tumor in relation to the blood vessels, particularly the pulmonary veins. In Case 3, at operation hilar involvement by the tumor was found to have encroached upon the pulmonary vessels. In Case 4, the large fibroma anteriorly located, arising in the interlobar fissures close to the hilum, could have impeded easily by its weight the return flow of blood through the pulmonary veins, particularly with the patient lying in bed. In Case 5, there was definite autopsy evidence of the growth of the tumor into the pulmonary vein. With the knowledge clinically that a definite peripheral cyanosis existed in each instance, these observations may serve inadequately to lend support to the theory that faulty aeration of a portion of the lung may lead to osteoarthropathy.

CONCLUSIONS

Hypertrophic pulmonary osteoarthropathy may be the initial symptom in intrathoracic tumors.

Occurring abruptly, it may simulate an arthritic condition and be confused with it in the absence of symptoms referable to the chest.

Two patients in whom the tumors were removed, one who had a pneumonectomy for a bronchiogenic carcinoma, and the other with a benign fibroma, had an abrupt disappearance of their symptoms following operation.

Evidence of chronic anoxemia as the cause of osteoarthropathy exists, and involvement of the vessels may be the cause of faulty aeration of the blood in the involved portion of the lung.

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DISCUSSION

DR. JOHN S. HARTER, SANATORIUM, MISS.—A few years ago, working with Dr. Churchill at the Massachusetts General Hospital, we tried to reproduce this disease in animals, without success. There are numerous reports in the literature of the occurrences of pulmonary osteoarthropathy in various types of animals. We tried particularly the ligation of the bronchus to one or more lobes of cats. We also ligated the bronchus to one lobe in a monkey, without success. The trouble with trying to form any one theory as to the cause of pulmonary osteoarthropathy is that somebody always brings up a case that does not fit the theory. There are several cases reported, and we had one at the General Hospital, of unilateral clubbing of the fingers due to aneurysm of the subclavian artery. There seems to be no single explanation for the occurrence of club fingers in all the different diseases with which it is found associated.

I might add an observation on the capillaries of the nail beds. I believe there is but one article in the literature on this subject. The capillaries of the nail beds are found to be greatly elongated, sometimes from ten to fifteen times the normal length. The circulation is very slow, and several red cells may lie side by side due to the increased size of the capillary. One may easily follow individual cells around the loop, which is difficult in the normal nail bed. After the removal of the cause of the club fingers, the capillaries return somewhat to the normal. Possibly, if followed long enough, they would become almost completely normal.

THE ROLE OF PLEURAL LYMPHATICS IN THE PATHOGENESIS OF COLD ABSCESSES OF THE CHEST WALL AND PARAVERTEBRAL ABSCESSES*

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IN 1894 Souligoux[1] demonstrated lymph channels in pleuritic adhesions and showed that these channels communicate with lymph vessels in the chest wall. His statements indicate that he believed that tubercle bacilli are conveyed along these channels to the parasternal lymph nodes. He found that the parasternal lymph nodes in patients with pulmonary tuberculosis and tuberculous empyema, who come to necropsy, are frequently large and caseous. He noted that cold abscesses of the chest wall develop at the site of the parasternal lymph nodes in a certain number of patients who have had a purulent pleurisy and that these abscesses frequently involve only the soft tissues of the chest wall. He concluded that the breaking down of tuberculous parasternal lymph nodes is a common cause of spontaneous cold abscesses of the chest wall.

Between 1930 and 1936 Kaufman[2-5] showed, by histologic examination of tissues removed at operation and by dissection of cadavers, that most spontaneous cold abscesses of the chest wall take origin in caseous parasternal lymph nodes. He also drew attention to the fact that approximately one-third of the patients with cold abscesses of the chest wall whom he had seen had roentgenographically demonstrable pleurisy.

Kaufman, in addition to demonstrating the mode of origin of cold abscesses of the chest wall, assembled evidence which suggests that tuberculous lymph nodes lying close to the vertebral column sometimes give rise to paravertebral abscesses and tuberculosis of the spine.

The observations which will be presented in the present paper shed new light on the manner in which particulate matter—finely divided lampblack, colloidal thorium dioxide, and tubercle bacilli—is removed from the pleural spaces. They support and amplify the observations of Souligoux and Kaufman concerning the mode of origin of cold abscesses of the chest wall. They also lend weight to Kaufman's suggestion that tuberculous lymph nodes may, on occasion, give rise to paravertebral abscesses and to superficial and deep ulceration of the spine.

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The present study consists of two parts, namely, (1) a study of the lymph drainage of the pleural spaces of experimental animals and (2) a study of human necropsy material.

EXPERIMENTAL DATA

Two methods were employed in the study of the lymph drainage of the pleural spaces: (1) Guinea pigs, rabbits, and cats were injected intrapleurally with a mixture of colloidal thorium dioxide and finely divided lampblack, photographed roentgenographically at intervals, and killed at selected periods and examined macroscopically; (2) guinea pigs alone were injected intrapleurally with a suspension of tubercle bacilli in isotonic saline and killed at appointed intervals, and the tissues were examined macroscopically and microscopically. To facilitate the injection of the thorium dioxide-lampblack mixture or the suspension of tubercle bacilli into the pleural space, a three-way petcock, a water manometer, a syringe, and a blunt hypodermic needle were employed. Each animal was given but a single intrapleural injection. The injection mixture, or suspension, was introduced into the right pleural space in some instances and into the left pleural space in other instances. The thorium dioxide preparation* used in these experiments was similar to that employed by Menville and Ané (1932, 1934)[6, 7] in their roentgenographic studies of lymph nodes. The suspensions of tubercle bacilli used in the intrapleural injections were made by triturating measured quantities of avirulent tubercle bacilli (Strain R_1, Saranac Laboratory) or virulent human tubercle bacilli (Strain H_{37}, Saranac Laboratory) in isotonic saline. Animals were killed at intervals of days and weeks up to two months following the intrapleural injections.

Intrapleural Injections of Colloidal Thorium Dioxide and Lampblack: a. In Guinea Pigs.—Nineteen healthy guinea pigs were injected intrapleurally with a mixture of colloidal thorium dioxide and finely divided lampblack. One group of animals, ten in number, was given the injection mixture in an amount of 0.25 c.c. Two other groups, one of four and the other of five animals, were injected intrapleurally with 0.1 c.c. and 0.5 c.c. of the mixture, respectively. The results of the experiments in all of the groups were comparable.

The following protocol contains the findings in a representative guinea pig in the group of ten animals.

> In this guinea pig (No. 421), 0.25 c.c. of a mixture of colloidal thorium dioxide and finely divided lampblack was introduced into the right pleural space. Chest roentgenograms (posteroanterior and lateral) made a day after the injection disclosed dense shadows of varied size and shape in both lung fields and several discrete ovoid densities proximate to the shadow of the sternum. Roentgenograms taken five days after the injection and immediately before the guinea pig was killed presented shadows similar to those just described and, in addition, two dense elliptic shadows near the outline of the first lumbar vertebra.
>
> The visceral and parietal pleurae on both sides were studded with patches of black exudate. The parasternal lymph nodes, which lie external to the parietal pleura in the intercostal spaces close to the lateral borders of the sternum, were jet-black. A group of retroperitoneal lymph nodes situated close to the lateral surfaces of the first lumbar vertebra were also jet-black. The other

*The thorium dioxide preparation used is known as thorotrast. This preparation is impervious to roentgen rays and has, as Menville and Ané pointed out, a special affinity for lymphoid tissue.

lymph nodes, including the tracheobronchial nodes, and the viscera were free from deposits of lampblack.

Stereoscopic examination of roentgenograms of the inflated excised lungs showed dense discrete shadows at the margins of the lung fields. A roentgenogram of the sternum disclosed discrete ovoid densities proximate to the outlines of several of the segments of the sternum. The striking features of a roentgenogram of the torso were two dense elliptic shadows lying close to the shadow of the first lumbar vertebra. (Figs. 1 and 2 illustrate the roentgenologic and necropsy findings in this guinea pig.)

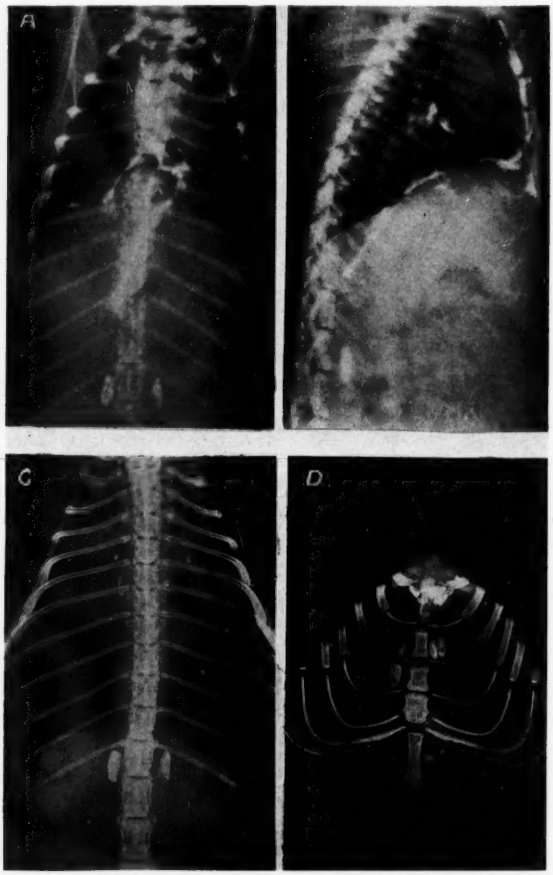

Fig. 1.—Guinea pig No. 421. *A*, Chest roentgenogram (posteroanterior) made on the fifth day. There are dense shadows of varied size and shape in both lung fields and two dense elliptical shadows near the outline of the first lumbar vertebra.

B, Chest roentgenogram (lateral) made on the fifth day. There are ovoid densities proximate to the shadow of the sternum and an elliptical shadow near the outline of the first lumbar vertebra.

C, Roentgenogram of a portion of the vertebral column. Two dense elliptical shadows appear near the outline of the first lumbar vertebra.

D, Roentgenogram of a portion of the chest wall. There are ovoid densities proximate to the shadow of the sternum.

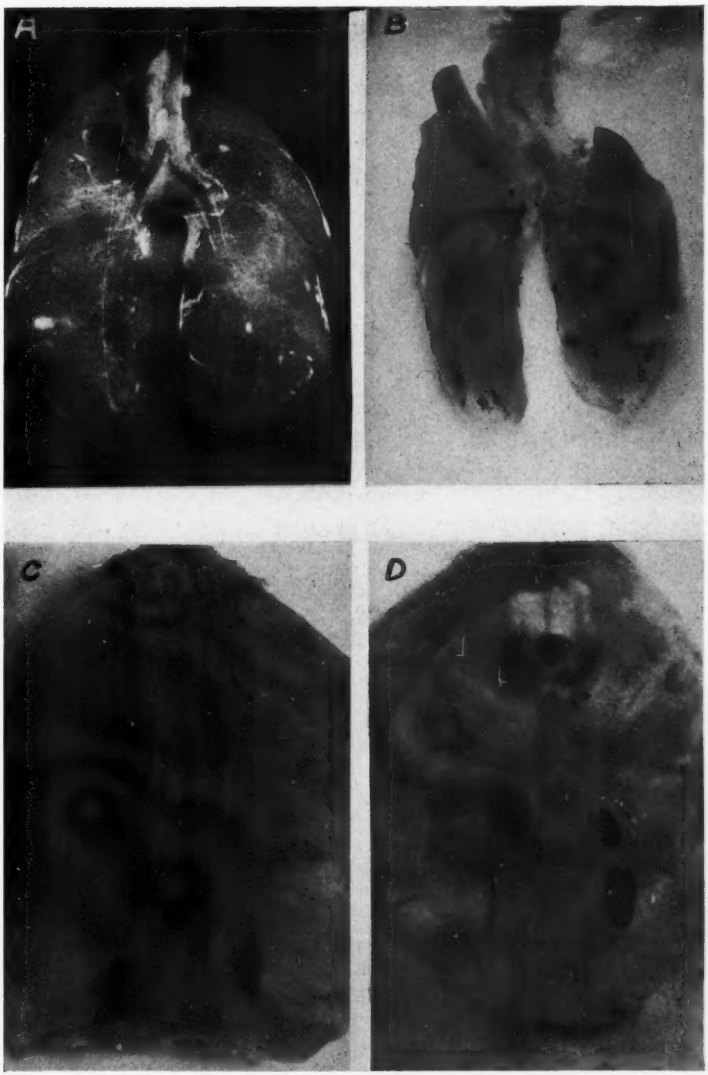

Fig. 2.—Guinea pig No. 421. *A*, Roentgenogram of the excised inflated lungs. Numerous small dense shadows appear, which proved, on stereoscopic examination, to be at the margins of the lung fields.

B, Photograph of the excised lungs. There are black deposits on the visceral pleura of both lungs, but no black material appears in the paratracheal lymph nodes.

C, Photograph of a portion of the vertebral column. There are black deposits on the parietal pleura and large, black para-aortic lymph nodes.

D, Photograph of a portion of the chest wall, showing large, black parasternal lymph nodes.

An analysis of the roentgenologic and anatomic findings of the nineteen guinea pigs injected intrapleurally with the mixture of thorium dioxide and lampblack disclosed the following points. Deposits of the injection mixture were found in both pleural spaces in every animal. Traces of thorium dioxide and lampblack were found in the parasternal lymph nodes of two animals approximately four hours following the intrapleural injection. Necropsy examination showed that a paired group of retroperitoneal lymph nodes, situated near the attachments of the diaphragmatic crura, frequently contained small deposits of the injection mixture as early as the second day following the intrapleural injection. Roentgenograms, taken on the third day, regularly revealed evidence of deposits of thorium dioxide in both the parasternal and the retroperitoneal lymph nodes. All examinations, whether roentgenographic or anatomic, made after the third day and up to the end of the second month, when the last animal was killed, disclosed the presence of thorium dioxide and lampblack in both the parasternal lymph nodes and the retroperitoneal lymph nodes mentioned above. Traces of thorium dioxide and lampblack were found in the paratracheal lymph nodes of two animals and in a small thoracic paravertebral lymph node in one animal. No deposits of the injection mixture were detected in the tracheobronchial or other lymph nodes of any of the guinea pigs other than those just mentioned. The viscera of all the animals were, as far as we could determine, free from deposits of the injection mixture.

The foregoing observations and the accompanying illustrations demonstrate that a mixture of colloidal thorium dioxide and finely divided lampblack introduced into the pleural spaces of guinea pigs is, in part at least, regularly conveyed to two groups of lymph nodes, namely, (1) the parasternal nodes and (2) a cluster of retroperitoneal lymph nodes situated close to the descending aorta at the level of the lower thoracic or upper lumbar vertebrae. The latter cluster of nodes will, for convenience's sake, henceforth be called the para-aortic lymph nodes. The evidence at hand indicates that particulate matter which is introduced into the pleural spaces of healthy guinea pigs is rarely, if ever, transported to the tracheobronchial or paratracheal lymph nodes.

b. In Rabbits.—Ten healthy rabbits were injected intrapleurally with either 0.25 or 0.5 c.c. of the mixture of colloidal thorium dioxide and finely divided lampblack. Roentgenograms of the rabbits were taken at intervals. Animals were killed two days, two weeks, and four weeks following the intrapleural injections. Examination of the rabbits showed that the injection mixture remained on the injected side and that, as a rule, only the parasternal lymph nodes on the injected side contained deposits of thorium dioxide and lampblack. Traces of the injection mixture were noted in the parasternal lymph nodes on the contralateral side in only two instances. No deposits of thorium dioxide and lampblack were found in sites similar to the sites of the para-aortic lymph nodes in guinea pigs. Rabbits do not appear to have retroperitoneal lymph nodes comparable to the para-aortic

lymph nodes in guinea pigs. The tracheobronchial and other lymph nodes contained, so far as we could determine, no deposits of the injection mixture. The viscera, including the lungs, were devoid of thorium dioxide and lampblack.

This experiment demonstrates that particulate foreign material introduced into the pleural spaces of rabbits is conveyed, as in guinea pigs, in part at least, to the parasternal lymph nodes. It also shows that the lymph drainage of the pleural spaces of rabbits differs from that of guinea pigs in the following respects: Foreign material is transported, as a rule, only to the parasternal lymph nodes on the injected side; particulate matter injected intrapleurally apparently is not conveyed to retroperitoneal lymph nodes.

c. In Cats.—Two cats were injected intrapleurally with the mixture of colloidal thorium dioxide and finely divided lampblack. One animal was injected in the right side; the other animal, in the left side. Each animal was given 2.0 c.c. of the mixture. Special roentgenograms of the cat injected in the right side were taken on the fourth day following the injection. These roentgenograms disclosed dense abnormal shadows of varied size and shape in the right lung field. They failed to disclose abnormal shadows suggestive of deposits of radiopaque material in lymph nodes. The animal was killed on the fifth day. Necropsy examination disclosed a collection of clear serous fluid in the right pleural space and numerous patches of black exudate on the parietal and visceral pleura on the same side. There were a few small patches of black exudate on the parietal pleura on the left side. We were unable to find the parasternal lymph nodes. Two small black nodes were found in a site comparable to the site of the para-aortic lymph nodes of guinea pigs. The paratracheal lymph nodes and the viscera, including the lungs, were, so far as we could determine, free from deposits of thorium dioxide and lampblack. The cat which was injected in the left side was killed on the fourth day following the injection. Necropsy examination of this animal disclosed a picture similar to that found in the first-mentioned animal. Deposits of lampblack were found in only two groups of lymph nodes. One of these groups consisted of two nodes situated in the anterior mediastinum at the level of the third interspace; the other consisted of two small nodes which overlay the psoas portion of the iliopsoas muscle at the level of the point of origin of the left renal artery.

The evidence presented herein is too meager to permit of comment with respect to the lymph drainage of the pleural spaces of cats. Comparison of the results of this experiment and the results of the experiments with guinea pigs and rabbits injected intrapleurally with thorium dioxide and lampblack suggests, however, that there are considerable variations in the manner in which foreign material is removed from the pleural spaces of experimental animals.

Intrapleural Injections of Tubercle Bacilli in Guinea Pigs.—Two groups of vaccinated guinea pigs were injected intrapleurally with measured quantities of tubercle bacilli in suspension in isotonic saline. One group consisted of twenty animals; the other, of eight animals. Vaccinated guinea pigs were used because it was found, in a preliminary experiment, that the injection of virulent human

tubercle bacilli, even in small quantities, into the pleural spaces of healthy guinea pigs was followed by widespread dissemination of the bacilli and, frequently, death within from four to six weeks.

The group of twenty animals were inoculated in the groin with 0.25 c.c. of a suspension of avirulent tubercle bacilli (Strain R_v, Saranac Laboratory) in isotonic saline, approximately six weeks prior to the intrapleural injection. The suspension of avirulent tubercle bacilli had the appearance of ground glass. All of the guinea pigs gave positive reactions to Mantoux tests, with 0.1 c.c. O. T. in a dilution of 1 to 20, immediately prior to the intrapleural injection. Five of the twenty animals were set aside as controls. These animals were killed and examined at intervals during the course of the experiment. The remaining fifteen guinea pigs were injected intrapleurally with 0.25 c.c. of a suspension of avirulent tubercle bacilli (Strain R_v, Saranac Laboratory) in isotonic saline. The quantity of suspension injected into each animal contained approximately 1 mg. (moist weight) tubercle bacilli. These guinea pigs were killed at intervals following the intrapleural injection, some on the second day and others at the end of the first, second, third, and fourth weeks, respectively.

The results of the foregoing experiment were as follows. Necropsy examination of the control animals showed, in every instance, a cold abscess in the groin and enlarged external and internal iliac lymph nodes. Sections of the latter revealed vast accumulations of large, pale, mononuclear leucocytes and, in some instances, typical tubercles. The para-aortic lymph nodes were small, and, so far as we could determine macroscopically and microscopically, they contained no tubercles. The other lymph nodes appeared natural. There were no macroscopic lesions in the lungs, spleen, or other viscera. Necropsy examination of the guinea pigs injected intrapleurally showed that all had pleuritis in varying degrees and that all had abnormally large parasternal and para-aortic lymph nodes. Sections of parasternal and para-aortic lymph nodes, removed from animals killed at successive periods, disclosed collections of large, pale, mononuclear leucocytes of various sizes and, in some instances, a few small tubercles. Acid-fast bacilli were found in the parasternal and the para-aortic lymph nodes of six animals. The paratracheal and tracheobronchial lymph nodes of all except one of these animals were small. Sections of the paratracheal lymph node of the above-mentioned animal revealed a small collection of large, pale, mononuclear leucocytes. There were, with one exception, no macroscopic lesions in the lungs of any of these animals. The right lung of the guinea pig which was exceptional contained scattered pneumonic areas of undetermined etiology. No lesions, apart from the foregoing and certain lesions such as cold abscesses in the groin and enlarged external and internal iliac lymph nodes which were the result of the original subcutaneous injection of avirulent tubercle bacilli, were found in any of these animals.

The group of eight guinea pigs was vaccinated by inoculation in the groin with a heavy suspension of an attenuated culture of tubercle

bacilli several weeks prior to the intrapleural injection. Four of the animals were injected intrapleurally with 0.1 mg. of human tubercle bacilli (Strain H_{37}, Saranac Laboratory) in suspension in isotonic saline, and four, with 1.0 mg. of tubercle bacilli. The animals were killed at intervals of one, two, and three weeks. At necropsy one of the four animals injected intrapleurally with 0.1 mg. of tubercle bacilli presented pleuritic adhesions. No pleuritic adhesions were found in the remaining three animals. The parasternal lymph nodes of all of these guinea pigs were large and soft. Microscopic examination showed that they contained scattered tubercles. The para-aortic nodes of two of these animals were also somewhat larger than usual. Sections of one of these nodes disclosed no lesions. Sections of the other revealed several fibrous tubercles. The four guinea pigs injected intrapleurally with 1.0 mg. of tubercle bacilli presented, at necropsy examination, pleuritic adhesions and moderately large parasternal and para-aortic lymph nodes. Microscopic examination of both groups of lymph nodes disclosed vast collections of large, pale, mononuclear leucocytes, caseofibrous tubercles, and, in a few instances, acid-fast bacilli. The tracheobronchial and paratracheal lymph nodes of seven of the eight guinea pigs were natural. There were no macroscopic lesions in the lungs of the animals which had small tracheobronchial and paratracheal lymph nodes. The lungs of the animal which had enlarged paratracheal lymph nodes contained scattered tubercles and small areas of tuberculous pneumonia. There were cold abscesses in the groins of all the guinea pigs. The inguinal and the external and internal iliac lymph nodes in all the guinea pigs contained tuberculous lesions. The cold abscesses and the tuberculous inguinal and iliac lymph nodes were the result of the vaccinating inoculation in the groin.

The above-described experiments demonstrate that tubercle bacilli introduced into the pleural spaces of vaccinated guinea pigs are, like thorium dioxide and lampblack, transported, in part at least, to the parasternal and para-aortic lymph nodes. The experiments also show that tubercle bacilli which are transported from the pleural spaces to the parasternal and para-aortic lymph nodes frequently produce tuberculous lesions in these nodes in guinea pigs.

OBSERVATIONS ON HUMAN NECROPSY MATERIAL

Human necropsy material was studied in order to trace the lymph drainage of the pleural spaces in man. Forty-nine cadavers were examined. The cadavers included those of eighteen persons who presented no signs of pleurisy and thirty-one who had had pleuritis in varying degrees. Eighteen of the forty-nine were examined soon after the transport of thorium dioxide and lampblack from the pleural spaces to the parasternal lymph nodes in experimental animals was demonstrated and before it was recognized that thorium dioxide and lampblack may, in

certain animals, be carried to the retroperitoneal lymph nodes. No attempt was made in the case of these eighteen cadavers to search for lymph nodes other than the parasternal lymph nodes. Efforts were made in the remaining thirty-one to search for all lymph nodes to which foreign matter in pleural exudates or pleuritic adhesions might be carried. The results of these observations on human necropsy material will be presented under two headings: (1) Cadavers in which a search was made for parasternal lymph nodes, and (2) cadavers in which a search was made for various lymph nodes.

*Cadavers in Which a Search Was Made for Parasternal Lymph Nodes.**—Eighteen cadavers were examined. Twelve of the cadavers had no pulmonary or pleural lesions. The parasternal lymph nodes of these cases were minute, measuring, as a rule, only from 1 to 2 mm. in diameter. Six of the cadavers had pulmonary tuberculosis and localized or widespread plastic pleuritis. The parasternal lymph nodes of these persons were large. They measured from 0.5 to 3.0 cm. in diameter. Those having extensive pleuritis had, as a rule, larger parasternal lymph nodes than those with localized pleuritis. Microscopic examination of sections of the parasternal lymph nodes of these cadavers disclosed typical tuberculous lesions. (Fig. 3*C* is a reproduction of a photograph of the parasternal lymph nodes in a cadaver observed by Dr. Jones.)

Cadavers in Which a Search for Various Lymph Nodes Was Made.—This group comprises thirty-one cases, consisting of (1) cadavers of six persons who died of extrapulmonary disease and who were, so far as we could determine, free from pleuritis and (2) those of twenty-five persons who had pleuritis in various degrees. All except one in the latter group died of ulcerative pulmonary tuberculosis. The exceptional case died of miliary tuberculosis.

Examination of the six cadavers which presented no signs of pleurisy disclosed small parasternal lymph nodes in the second intercostal spaces in most instances and in the first, the third, and the fifth intercostal spaces in some instances. These nodes were natural in appearance. In one case a small cluster of lymph nodes was found in the retroperitoneal space near the vertebral attachments of the diaphragmatic crura. Microscopic examination of sections of these nodes, as also of sections of the parasternal nodes of three of the cadavers, failed to reveal any lesions. The thoracic paravertebral nodes were not identified. The tracheobronchial lymph nodes appeared natural.

The findings in the twenty-five cadavers of persons who had had pleuritis were very different from those in the persons who did not have pleuritis. One or more of the parasternal lymph nodes of practically all of the cadavers was abnormally large. The first and second interspaces contained large nodes more frequently than the other interspaces. Large

*These cases were observed by Dr. Julia Mary Jones, of the Department of Anatomy of Duke University, Durham, N. C., who has kindly given us permission to include her observations in this study.

lymph nodes were, however, found in all of the interspaces from the first to the sixth, inclusive. Microscopic examination of sections of these nodes invariably revealed tuberculous lesions. One parasternal lymph node, which was sectioned, contained an area of caseation approximately

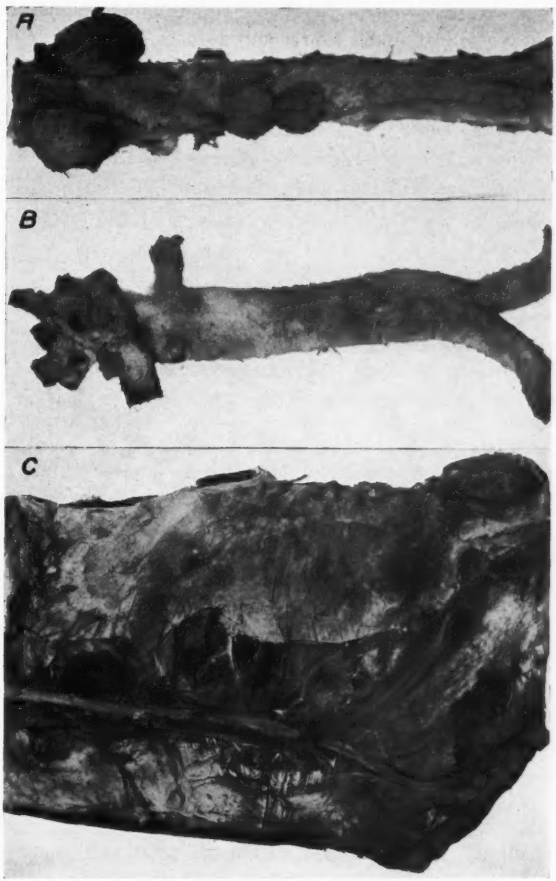

Fig. 3.—Human necropsy material. *A*, Case 111. Photograph of abdominal aorta (dorsal surface) and four para-aortic lymph nodes. The cut surface of one of the large nodes ranged in color from gray to black.

B, Case 115. Photograph of abdominal aorta (dorsal surface) and para-aortic lymph nodes. There are two small nodes showing black on the cut surface and also slightly larger pale gray nodes.

C, Photograph of a portion of the sternum of one of the cadavers examined by Dr. Jones. There is a large parasternal lymph node near the internal mammary vessels at the left side of the photograph.

1 cm. in diameter. Clusters of lymph nodes were found in the retroperitoneal space near the vertebral attachments of the diaphragmatic crura in ten of the twenty-five cadavers. In one instance, a single isolated caseous abscess (3.0 by 2.0 by 0.5 cm.) was found in the sheath

of the psoas portion of the left iliopsoas muscle. The abscess was situated at the level of the above-described retroperitoneal lymph nodes. There were, so far as we could determine, no macroscopic lesions in the vertebrae of this case. Microscopic examination of the retroperitoneal lymph nodes in seven cases disclosed tuberculous lesions. Enlarged thoracic paravertebral nodes were found in only one cadaver. These proved on section to be tuberculous. The paratracheal and tracheobronchial lymph nodes of all of the cases were abnormally large, sequelae presumably of the pulmonary disease. Tuberculous lesions were found in the mesenteric lymph nodes of a number of cadavers, particularly those of persons who had had ulcerative intestinal tuberculosis.

The findings in two of the foregoing cases are given.

These persons had been iron miners for years before they became ill and died. They had, during the course of their work, inhaled dust containing finely divided magnetite and quartz.

Post-mortem examination showed that both persons had extensive silicotuberculosis. The lungs were jet-black. Both had extensive pleuritic adhesions and a unilateral pocketed pleural effusion. There were collections of black material in the pleurae and in many of the pleuritic adhesions. The parasternal lymph nodes were large and ranged in color from dark gray to black. Histologic examination of selected portions of these nodes revealed hyaline silicotic nodules and fibrous tubercles containing lymphocytes and a few giant cells. The lymph nodes situated in the retroperitoneal space at the level of the vertebral attachments of the diaphragmatic crura were also large. Some were light gray; others were dark gray or black. They, like the parasternal lymph nodes, contained silicotic nodules and tubercles. The thoracic paravertebral nodes were not identified. The mesenteric lymph nodes of both cadavers were small. They contained no macroscopic black material. (Fig. 3, *A* and *B*.)

The foregoing observations demonstrate that in man tuberculous pleuritis is associated frequently with tuberculosis of the parasternal lymph nodes and, on occasion, with tuberculosis of a group of retroperitoneal lymph nodes situated near the vertebral attachments of the crura of the diaphragm, the so-called para-aortic lymph nodes.

Comparison of the necropsy findings in man and the observations obtained in experiments on animals shows that there is a striking similarity in the lymph drainage of the pleural spaces in man and in the guinea pig.

DISCUSSION

The observations recorded herein corroborate the generally accepted view that pleural lymphatics drain, in part at least, to the parasternal lymph nodes. They also disclose that, in guinea pigs and probably in man, pleural lymphatics regularly communicate with a group of retroperitoneal lymph nodes situated near the vertebral attachments of the diaphragmatic crura.

Souligoux was of the opinion that tubercle bacilli are carried from the pleurae to the parasternal lymph nodes by way of lymph channels in pleuritic adhesions. Further studies may show that in certain instances this is the case. The fact that particulate matter introduced into the pleural spaces of experimental animals is, within a day or two, transported to the parasternal and para-aortic lymph nodes indicates, we believe, that existing lymph channels can, and probably frequently do, effect the transfer. This view, furthermore, appears to be supported by the fact that a few guinea pigs which showed definite evidence of the transfer of tubercle bacilli from the pleural spaces to the parasternal and para-aortic lymph nodes presented no signs of pleurisy.

The observation that the pleural lymphatics of some animals, and probably of man, regularly communicate with a group of lymph nodes situated near the vertebral attachments of the diaphragmatic crura does not appear to have received adequate attention. Cunningham (1916)[8] was apparently the first investigator to draw attention to the fact that pleural lymphatics have afferents which traverse the diaphragm. He noted in a study of the development of the lymphatics of the lungs in the embryo pig that some pleural lymphatics appear to drain to preaortic lymph nodes by way of the ligamentum pulmonale. In 1928 Scott and Beattie[9] noted that in primates and man there is a cluster of lymph nodes, situated near the descending aorta at the level of the celiac artery, which receives afferents from the lower portion of the thoracic wall. They called these nodes the para-aortic lymph nodes. They appear, however, to have failed to appreciate the significance of this observation, for, in their study of the distribution of tuberculous lesions, they note only that the para-aortic nodes may, on occasion, become tuberculous when the normal lymph drainage channels of the lungs are blocked. Menville and Ané (1934), whose method for tracing lymphatics was followed in part of the experimental work reported herein, used rats, dogs, and rabbits in their study. They found, as we did, that particulate matter introduced into pleural spaces is promptly conveyed to the parasternal lymph nodes. They obtained evidence suggesting that thorium dioxide injected intrapleurally may, in some instances, be conveyed through the diaphragm to lymph nodes situated apparently in the retroperitoneal space. This observation is similar to, though not as striking as, our findings in this connection. Menville and Ané noted that thorium dioxide injected intrapleurally is also conveyed to the tracheobronchial lymph nodes. Our observations indicate that particulate matter injected intrapleurally is carried to the tracheobronchial lymph nodes only when it is accidentally introduced into pulmonary tissue.

The experiments in which tubercle bacilli were injected intrapleurally demonstrate not only that tubercle bacilli are conveyed from the pleural spaces to the parasternal and para-aortic lymph nodes, but also that bacilli so transferred incite tuberculous lesions in these lymph nodes. We have not as yet been able to demonstrate experimentally that tuberculous lesions in the parasternal lymph nodes can produce cold abscesses of the chest wall or that tuberculous foci in para-aortic lymph nodes can cause paravertebral abscesses. Experiments in progress at present will, we hope, shed light on these points.

Our observations support the observations of Souligoux and Kaufman concerning the mode of origin of cold abscess of the chest wall. They also lend weight to Kaufman's suggestion that tuberculous lymph nodes may, on occasion, give rise to paravertebral abscesses and tuberculosis of the spine.

SUMMARY

Particulate matter—a mixture of colloidal thorium dioxide and finely divided lampblack, or tubercle bacilli in suspension in isotonic saline—injected into the pleural spaces of guinea pigs is, in part at least, transported to the parasternal and the para-aortic lymph nodes. (The para-aortic nodes consist of a group of nodes situated in the retroperitoneal space near the vertebral attachments of the crura of the diaphragm.)

Observations on human subjects who have come to necropsy indicate that in man tubercle bacilli and particulate matter, such as silicious material, are conveyed from the pleural spaces to the parasternal and the para-aortic lymph nodes.

The foregoing evidence and the observations of Souligoux and Kaufman indicate that the steps in the evolution of a spontaneous cold abscess of the chest wall in man are as follows. Tubercle bacilli invade the pleural space and set up a local or widespread pleuritis. Some bacilli are transported from the pleural space to the parasternal lymph nodes. These nodes become caseous and rupture. Necrotic and caseous material burrows externally to form a cold abscess of the chest wall.

Furthermore, the evidence presented herein makes it seem probable that the transfer of tubercle bacilli from the pleural spaces to the para-aortic lymph nodes may, in certain instances, play a part in the evolution of paravertebral abscesses.

We acknowledge, with appreciation, the assistance which Dr. Bray and the staff of the New York State Hospital for Incipient Pulmonary Tuberculosis, Ray Brook, N. Y., have given us in this study. We are grateful to the directors and staffs of the Department of Pathology of the Montreal General Hospital and of the Pathological Institute of McGill University, Montreal, Quebec, for assistance in part of the experimental work and in the study of human necropsy material. We are also grateful to Professor Martin and Dr. O'Brien, of the Department of Anatomy of McGill University, Montreal, Quebec, for their contributions.

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A COMPARATIVE REPORT ON INFECTION OF THORACOPLASTY WOUNDS

Experiences With Ultraviolet Irradiation of Operating Room Air

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A DEEP wound infection following thoracoplasty is a serious complication. Difficulty in preventing a very rare, but occasional, severe wound infection stimulated our interest in Hart's[1] first report on the use of ultraviolet irradiation in the operating room and led us to an investigation of the problem of wound sepsis. Seven hundred and one consecutive thoracoplasties, performed during a period of two and one-half years, form the basis of this report. A reduction in the incidence of serious wound complications to 0.49 per cent, in clean cases, is attributed to a change in the technique of wound closure and to ultraviolet irradiation of the operating room air.

The problem of wound healing following thoracoplasty differs somewhat from the problem in the majority of general surgical operations. Tuberculous patients subjected to thoracoplasty have, in most instances, suffered a protracted illness and have had their protective mechanisms destroyed to varying degrees. The area of tissue exposed, the length of operating time, the degree of hemostasis, and the presence of a dead space beneath the scapula all enhance the possibility of any contaminating organisms gaining a foothold.

Life itself may be jeopardized by the septic process. An infection delays completion of surgical therapy. Marked thickening of fascia and an increase in regenerated osseous tissue, which is a likely sequel to infection, render subsequent procedures more difficult and less effective. A lowering of the patient's general resistance increases the risk of an extension and lessens the likelihood of arresting the tuberculous process. If a draining sinus forms in the chest wall of a tuberculous subject, there is a definite possibility of its developing into a chronic or permanent tuberculous sinus. A long period of decreased scapular motion, due to a discharging wound, may leave the patient with an arm and shoulder of limited usefulness. Butler[2] states that wound infections, including those of minor degree, are more frequently the cause of difficulty after thoracoplasty than any other complication. The lessening of the risk of wound sepsis is given by Head[3] as one of his reasons for using multiple and short incisions in thoracoplasty.

Read before the Twenty-Second Annual Meeting of The American Association for Thoracic Surgery at Los Angeles, Calif., July 5, 6, and 7, 1939.

From the New England Deaconess and Corey Hill Hospitals, and the Rhode Island State Sanatorium.

Bacterial contamination occurs in all wounds at the time of operation, as shown by Meleney,[4] Hart,[5] Ives and Hirshfeld,[6] and Hunt.[7] The number and virulence of the organisms introduced is such that a patient with good general resistance can usually overcome the invasion without developing clinical evidence of wound suppuration. Should resistance be low, varying degrees of sepsis may follow. If bacterial contamination is great, an infection of the wound may result, regardless of the condition of the patient.

Surgeons generally will not admit that infections are common. However, Meleney,[4] Goff,[8] and Hunt[7] have shown that the incidence of infection following general surgical operations varies from 12 to 33 per cent, if an accurate record is maintained of all cases. Hart[1, 5] reported that 33 per cent of 110 thoracoplasties performed before he began the use of ultraviolet radiation developed some wound complication postoperatively. We began to keep an accurate record of all wounds three years ago and were surprised to find that 13.8 per cent of wounds following thoracoplasty (clean cases) showed some evidence of infection (Table I).

TABLE I

INCIDENCE OF WOUND INFECTION BEFORE CHANGE IN WOUND CLOSURE OR ADOPTION OF ULTRAVIOLET RADIATION

NO. OF THORACOPLASTIES	NO. OF SUPERFICIAL INFECTIONS	PERCENTAGE	NO. OF DEEP INFECTIONS	PERCENTAGE	TOTAL NO. INFECTED	PERCENTAGE
29	3	10.3	1	3.4	4	13.8

TABLE II

INCIDENCE OF WOUND INFECTION AFTER CHANGE IN WOUND CLOSURE BUT BEFORE ULTRAVIOLET IRRADIATION

HOSPITAL	NO. OF THORACOPLASTIES	NO. OF SUPERFICIAL INFECTIONS	PERCENTAGE	NO. OF DEEP INFECTIONS	PERCENTAGE	TOTAL NO. INFECTIONS	PERCENTAGE
Deaconess	101	2	1.99	4	3.96	6	5.94
Corey Hill	160	7	4.38	4	2.5	11	6.88
Total	261	9	3.44	8	3.06	17	6.53

The sources of wound contamination are many. Improper sterilization of supplies is the most easily controlled. The opening of contaminated viscera, which is frequently necessary in general surgery, is a rare occurrence during thoracoplasty and, therefore, is a very infrequent source of sepsis. The patient's skin cannot be completely sterilized.[9] Nye,[10, 11] Meleney,[4] and Price[9] have reported iodine as being the most acceptable preoperative skin preparation, and it has been used throughout our entire series.

Staphylococci, the cause of 64 per cent of wound infections in our experience, are frequently found in the skin, and attention was first directed to this source of contamination. When an infection near a skin suture did occur, we observed that it was likely to be present around a consecutive series of sutures. The use of a continuous suture in the

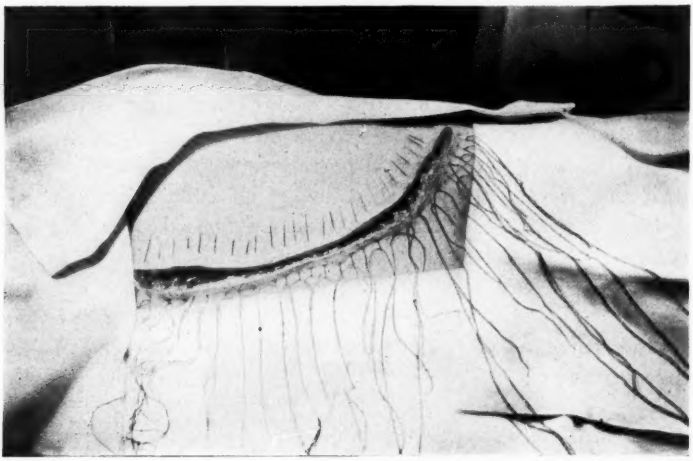

Fig. 1.—Photograph of wound at time of skin closure, illustrating the use of individual milliners' needles.

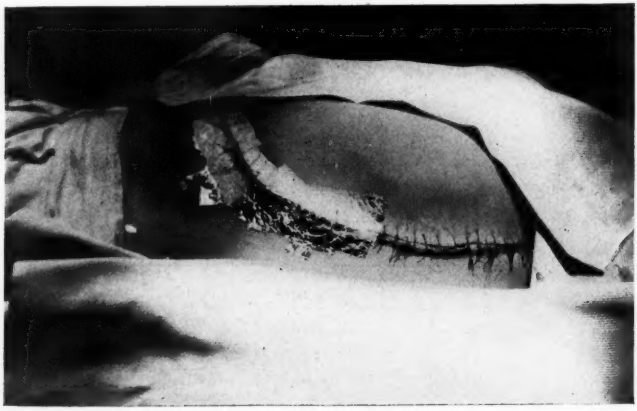

Fig. 2.—Photograph of wound after closure, showing application of silver foil.

skin was then discarded, and individual milliners' needles with very fine silk were substituted (Fig. 1). Silver foil has also been used to cover the suture line (Fig. 2). Following the institution of this method of closure, seventeen infections occurred in 261 wounds (6.53 per cent) (Table II).

AIR OF THE OPERATING ROOM AS A POSSIBLE SOURCE OF WOUND CONTAMINATION

Wells,[12-15] in 1933, published his first report on air-borne infection. The air of the operating room as a source of wound infection, however, received very little consideration until two or three years later. Hart,[1, 5, 16, 17] Gordon and Hart,[18] Meleney,[4] Wells,[19] Hunt,[7] and Cowan[20] have since published reports indicating the potentialities of this source of wound contamination. Meleney estimates that from 30,000 to 60,000 bacteria settle on the sterile operative field during the course of one hour. Whether or not the wound will become clinically infected depends upon the dosage of bacteria and the patient's general resistance. Although a certain number of organisms gain entrance to every wound, reducing the bacterial load should diminish the frequency of clinically significant wound complications.

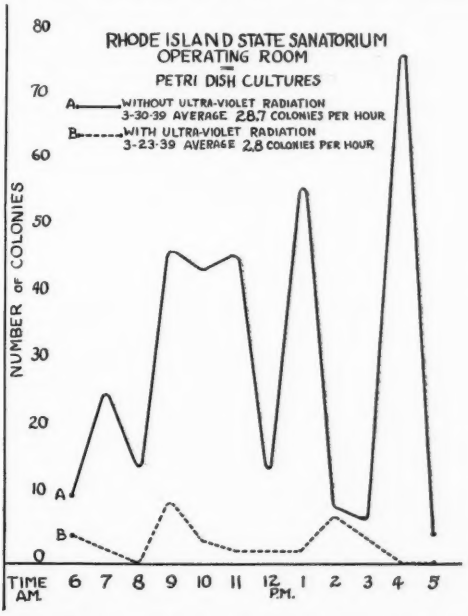

Fig. 3.—Chart showing bacterial load during a twelve-hour period, with and without irradiation of operating room air. Petri dishes were exposed for one-hour periods consecutively for twelve hours, on two different days. One test (*A*) was run with ultraviolet units turned off. Another test (*B*) was run with ultraviolet units turned on. The tests commenced at 6:00 A.M. Occupancy began at 7:00 A.M., and operations were in progress from 8:00 A.M. until 12:00 noon, and from 1:00 P.M. until 3:00 P.M. The room was cleaned between 4:00 P.M. and 5:00 P.M. Note the marked increase in the bacterial load (Curve *A*) during periods of increased activity. Also, note the marked reduction of the bacterial load (Curve *B*) on the day when the air was irradiated.

Exposure of Petri dishes is a simple test widely practiced in determining the hazards of air infection in operating rooms. While this method does not measure the concentration of organisms in the air or the rate of elimination of these organisms, it does indicate what actually falls out of the air in a given time on a given surface under given conditions.

Cultures of air within the operating room in our own experience have conformed to previous reports.[1, 4] In a series of fifty-five Petri dish cultures each exposed for one hour, the colony count averaged 33.7 (Table III). The number of colonies was

TABLE III

PETRI DISH CULTURES FROM OPERATING ROOMS

	NO. OF PLATES EXPOSED	TOTAL NO. OF COLONIES	AVERAGE NO. OF COLONIES PER PLATE PER HOUR
Without ultraviolet	55	1,854	33.7
With ultraviolet	108	594	5.5

found to increase in proportion to the number of occupants in the room and with the duration of occupancy (Fig. 3). At the New England Deaconess Hospital, where the operating room most frequently used for thoracic operations is small, an average of 65.1 colonies per hour was recovered during the time an operation was in progress. The location of the operating suite, its relation to corridors and elevator shafts, together with the lack of a modern type of ventilating system, all tended to increase the bacterial load of the operating room air.

STERILIZATION OF AIR BY ULTRAVIOLET IRRADIATION

In 1935, Wells[21, 22] reported on the bactericidal effects of ultraviolet irradiation on colon bacilli. Hart[1] was the first to apply this agent against air-borne organisms in the operating room. In his type of installation, the source of the irradiation was close to the operative field and even closer to the surgeon and assistants. Protective measures (hoods, goggles, and ventilators) on the part of the operating personnel were necessitated.

In collaboration with W. F. Wells,* then at the Harvard School of Public Health, a design was worked out for the operating room at the New England Deaconess Hospital, which overcame some of these practical objections and yet conserved the benefits of irradiated air which had been demonstrated. Improvements in design were based upon principles governing the bactericidal action of ultraviolet radiation upon microorganisms suspended in air.[23] The coefficient of utilization of lethal radiation depends upon the length of the path between the burner and the absorptive medium surrounding the air chamber (walls, ceiling, floor, etc.). By locating the lights in the angles formed by the ceiling and walls, it is possible to obtain a diagonal dimension and double the mean length of path of the light rays and, therefore, to increase proportionately the lethal usefulness of these rays. While the reflector necessary for this purpose absorbs some portion of reflected light, this loss is smaller than the gain through lengthening the rays.

By removing the source to a greater distance from the table, the degree of erythemal exposure of the operating team is more nearly that of the patient and calls for few precautions. Furthermore, the angle of the light rays is so steep that the eyes of the team are less exposed than the skin surfaces.

The lethal irradiation of the air in a room depends quite as much upon the distribution of the organisms in the room as it does upon the light sources.[23] It likewise depends upon the time of exposure as well as upon the intensity of the irradiation. By availing ourselves of the space in the operating room above the eye level for irradiation purposes, we are not limited to intensities tolerable to the operating team. Organisms, drifting with air currents through this highly lethal region, are intensely irradiated for considerable periods, and the concentration throughout the room thereby becomes markedly reduced. Thus, the room itself is converted into a purification chamber.

*Assistant Professor of Sanitary Engineering, University of Pennsylvania School of Medicine, Laboratories for the Study of Air-Borne Infection. Aided by a grant from the Commonwealth Fund.

The installation, adopted after considerable study of the bactericidal power of the burners then available, consisted of two pairs of 12-inch quartz mercury vapor tubes, emitting 95 per cent of their radiation in the 2537 Å wave band.[23]* One pair was placed high on either side of the operating room where the wall joined the ceiling (Fig. 4). They were fitted with suitable reflectors and directed toward the operative field. These tubes were 13 feet above the floor and 11 feet from the operating table. At this distance protection is not needed by those who wear glasses. A mild conjunctivitis may develop after prolonged exposure unless ordinary eyeglasses or a clerk's eyeshade are used.

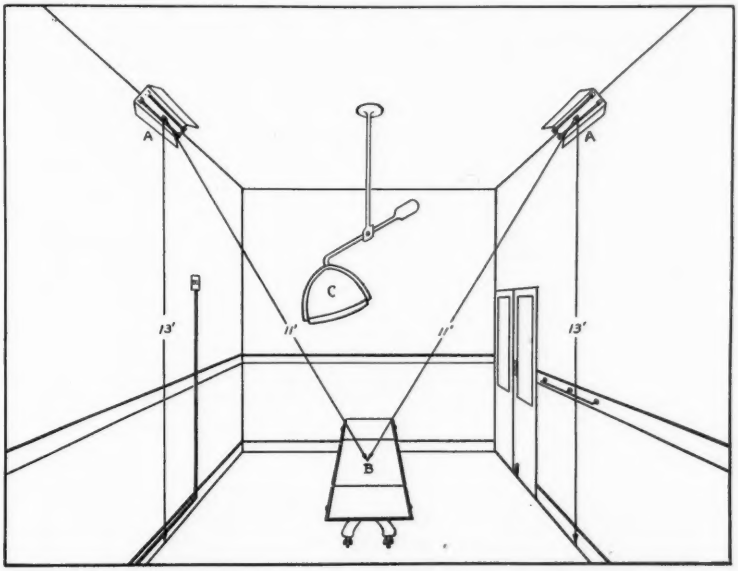

Fig. 4.—Diagram of operating room, illustrating the position of ultraviolet units, *A*, in respect to the walls of the room and the operating table, *B*; illuminating fixture, *C*.

TESTS OF BACTERICIDAL IRRADIATION

The lethal effectiveness of this installation was tested by the following method: Standard organisms *(Esch. coli)* were suspended by a standard infector (by atomization of a dilute culture), placing the infector at different points in the chamber and sampling at a point 3 feet above the operating table with an air centrifuge, an infectee. An electric fan was placed back of the infector to disperse these organisms throughout the room, building up a large bacterial concentration as indicated by the counts shown in Table IV (Tubes I, II, III, VI, VII, VIII, XI, XII, and XIII). Without altering this setup in any way, turning on the lights brought about a rapid reduction in the organisms (Table IV, Tubes IV, V, IX, X, XIV, and XV) (Fig. 5).

The degree of bactericidal irradiation demonstrated by this method is truly astonishing, but the test should not be misinterpreted. It measures the degree of irradiation in terms of units which can be compared with other tests of other combinations and other installations. It does not, however, arbitrarily demonstrate the impossibility of wound infection from bacteria passing through the air to the

*Manufactured by the Hanovia Company, Newark, N. J.

wound. Many factors may operate to protect organisms during passage. If included in masses of dust which are opaque to ultraviolet light, they are shielded. If clumps are passing through the light, some of the organisms may survive even if the majority are killed. If the time of exposure in passing through the light barrier is short, they may survive to reach the incision. The humidity of the air may affect the rate at which the organisms are killed by ultraviolet light. All of these factors must be determined independently after a study of the sources of bacteria, their state of suspension, and the ventilating conditions.

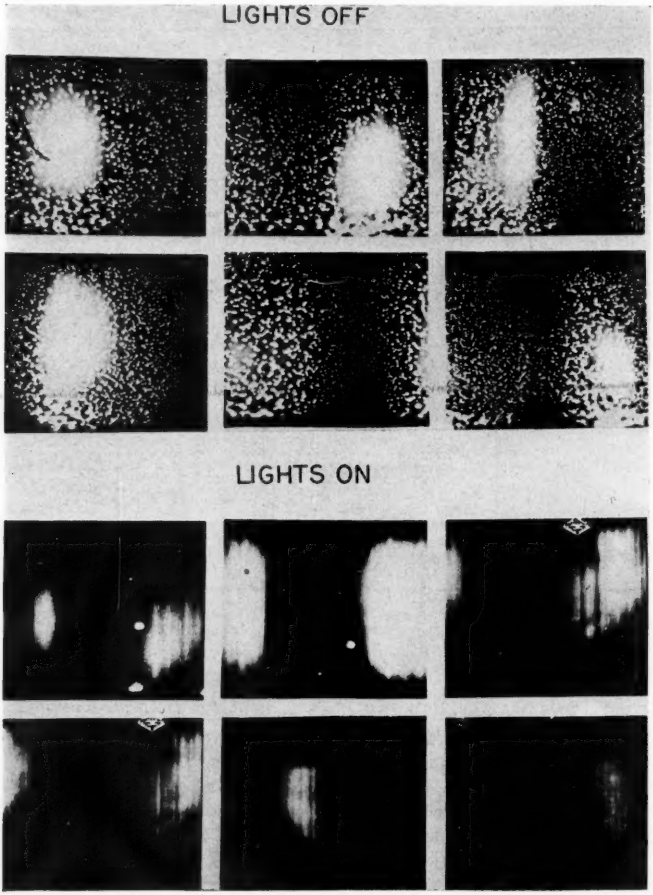

Fig. 5.—Operating room test. Photograph of sections of culture tubes used in determining lethal effect of ultraviolet irradiation upon colon bacilli. (See text for explanation of method.)

Ultraviolet irradiation is peculiarly effective against isolated organisms in fine particles; it complements other measures less effective for fine particles, but more effective against coarse particles, such as filtration, precipitation, exclusion, and effective masking of the personnel, to exclude the Flügge droplets which readily penetrate light barriers because of their proximity, velocity, and dampness.

TABLE IV

OPERATING ROOM TEST

(AIR CENTRIFUGE IN CENTER OF ROOM, ON OPERATING TABLE; INFECTOR, ON AT 3:26 P.M., RAN CONTINUOUSLY DURING TEST; *B. coli* TEST ORGANISM; EOSIN-METHYLENE BLUE AGAR)

TUBE	TIME, 10′ FOLLOWING	LOCATION OF INFECTOR	LIGHTS	COUNTS
I	3:53	Left corner, side opposite door	Off	489
II	4:03½	Left corner, side opposite door	Off	1,080
III	4:14	Left corner, side opposite door	Off	2,876
IV	4:26	Left corner, side opposite door	On (at 4:24½)	4
V	4:36½	Left corner, side opposite door	On	0
VI	4:52	Left corner, side of door	Off (at 4:47)	883
VII	5:02½	Left corner, side of door	Off	1,212
VIII	5:13	Left corner, side of door	Off	1,489
IX	5:25	Left corner, side of door	On (at 5:23½)	4
X	5:35½	Left corner, side of door	On	0
XI	5:51	Right corner, side opposite door	Off (at 5:46)	1,880
XII	6:01½	Right corner, side opposite door	Off	2,765
XIII	6:12	Right corner, side opposite door	Off	3,485
XIV	6:23¾	Right corner, side opposite door	On (at 6:22¼)	0
XV	6:34¾	Right corner, side opposite door	On	0

RESULTS OF IRRADIATION OF AIR OF THE OPERATING ROOM

In appraising the clinical results, all wound complications have been divided into two groups, superficial and deep. Any degree of sepsis, from a slight infection around one skin suture to more extensive infections of the subcutaneous tissues, but not involving the planes below the muscles, has been classified as a superficial infection. All such infections must have healed within two weeks postoperatively. Extensive involvement of the subcutaneous structures or infections that extended below the muscles were considered as deep infections. In order to reduce variables to the minimum, only records of wound healing following thoracoplasty have been utilized. Patients who had a previous wound infection or a bronchopleurocutaneous fistula were excluded in this study. The apex of the upper lobe has been mobilized when possible at the time of performance of the first-stage operation. Approximately 80 per cent of the patients were so treated. Subsequent stages were carried out without excising the scar of the previous operation.

Two hundred and eighty-seven thoracoplasties were performed under ultraviolet irradiation in one hospital. Of that group, five became infected; three of those infections were superficial, and two were deep infections. In a second hospital similarly equipped, 124 operations* were carried out. Six wounds became infected. The extent of the infection was limited in all cases to a small area about one or two skin sutures, and all were classified as superficial (Table V). Thus, in a total of 411

*A group of ten patients having revisional operations were not included in this study. All had been originally operated upon elsewhere, and the presence or absence of a wound infection following the preceding operation could not be determined.

operations, there were eleven infections (2.67 per cent); only two, or 0.49 per cent, were deep and of clinical significance.

TABLE V

INCIDENCE OF WOUND INFECTION AFTER CHANGE IN WOUND CLOSURE AND ADOPTION OF ULTRAVIOLET RADIATION

HOSPITAL	NO. OF THORACOPLASTIES	NO. OF SUPERFICIAL INFECTIONS	PERCENTAGE	NO. OF DEEP INFECTIONS	PERCENTAGE	TOTAL NO. INFECTED	PERCENTAGE
Deaconess	287	3	1.05	2	0.69	5	1.75
Rhode Island State Sanatorium	124	6	4.84	0	0.00	6	4.84
Total	411	9	2.17	2	0.49	11	2.67

SUMMARY

The reports from the literature indicate that some degree of wound infection occurs in approximately 15 per cent of all "clean" general surgical cases.

The incidence of infection in thoracoplasty wounds is believed to be even higher, due to the poor general resistance of the tuberculous patient, the size of the wound, the length of operating time, the inability to obtain complete hemostasis, and the presence of a large dead space.

A serious wound infection may completely nullify the patient's chance for recovery, due either to immediate or late results of the infection.

A change in the type of wound closure in a series of 261 thoracoplasties apparently reduced the total incidence of infection to 6.53 per cent.

The presence of pathogenic organisms in the air of the operating room has been well substantiated.

An ultraviolet installation was planned with which to utilize the entire operating room as a sterilizing chamber and to eliminate the objection to other types of units. Tests showed this method was 99.9 per cent effective in killing *B. coli,* and from 75 to 90 per cent effective against the staphylococcus.

Four hundred and eleven consecutive thoracoplasties have been performed under ultraviolet irradiation. The total incidence of wound infection was 2.67 per cent. All but two of the eleven infections were superficial. The incidence of clinically significant wound complications was 0.49 per cent.

We wish to express our indebtedness to Mr. Frederic T. Davis, 118 Washington Street, Malden, Mass., and to Miss Ruth Blumfeld, Department of Bacteriology, Boston University, for technical assistance in regard to the installation and testing of the ultraviolet units.

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1101 BEACON STREET
BROOKLINE, MASS.

DISCUSSION

DR. BETTS.—The equipment at the Deaconess Hospital was installed by the Hanovia Company on an experimental basis. They now have similar units on the market at $177.00 per unit.

CHRONIC INFLAMMATORY LESIONS OF THE LUNG SIMULATING BRONCHIOGENIC CARCINOMA

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DESPITE our more extensive knowledge of the disease and the application of a variety of investigative procedures, an exact diagnosis of bronchiogenic carcinoma cannot be established in every instance. Diagnostic difficulties still exist, particularly in those persons in whom the clinical picture suggests the presence either of an inflammatory lesion or of a carcinoma. In the literature particular attention has been devoted to those cases in which the bronchiogenic carcinoma simulated an inflammatory disease of the lung or pleura. Numerous observers, for example, have pointed out the frequency with which the clinical evidence of pulmonary abscess, bronchiectasis, or empyema may predominate so that the underlying tumor responsible for the suppurative process is overlooked.[4-7]

We have been interested, however, in a small group of patients in whom the opposite condition prevails and an inflammatory lesion is mistaken for a bronchiogenic carcinoma. It has been our experience that this type of patient has presented the most serious problem in differentiation, since the investigative measures usually relied upon to establish an accurate etiological diagnosis have been of little aid in clarifying the clinical and roentgenologic picture. Indeed, even with direct examination of the lung at exploratory thoracotomy, the surgeon may have considerable difficulty in determining the exact nature of the pulmonary lesion. Of the cases studied we shall illustrate the problem by reference to four patients in whom pneumonectomy was undertaken because of the impossibility of clearly differentiating between an inflammatory process and a tumor. In each instance the lung was available for pathologic study so that the true nature of the pulmonary disease could be ascertained.

Case 1.—I. C., a 54-year-old white man, was admitted to the Mount Royal Sanatorium on Aug. 28, 1935. For approximately one year he had fatigued easily. In July, 1935, he first noticed a slight nonproductive cough. After four weeks of irritative cough he developed a small amount of mucopurulent sputum and had one hemoptysis of 2 ounces. Weight loss of 10 pounds had occurred, and there was a daily temperature elevation to 100° F.

The only significant finding on physical examination was the presence of posttussive râles in the upper third of the right lung.

Read (by title) before the Twenty-Second Annual Meeting of the American Association for Thoracic Surgery, Los Angeles, Calif., July 5, 6, and 7, 1939.

From the Departments of Thoracic Surgery and Medicine, Cleveland City Hospital and Western Reserve University School of Medicine.

X-ray of the chest (Fig. 1) showed infiltration of slight density in the first and second anterior interspaces on the right side.

The clinical and roentgenologic picture suggested pulmonary tuberculosis, but this could not be substantiated by sputum examination, which was repeatedly negative for tubercle bacilli. However, because of the persistence of symptoms, a temporary phrenic nerve paralysis was done on Sept. 27, 1935. The diaphragm failed to become paralyzed until three weeks later, and this was attributed to extension of the lesion in the right upper lobe, with involvement of the phrenic nerve. Following operation, cough and expectoration increased. There was an evening temperature elevation to 100° F.

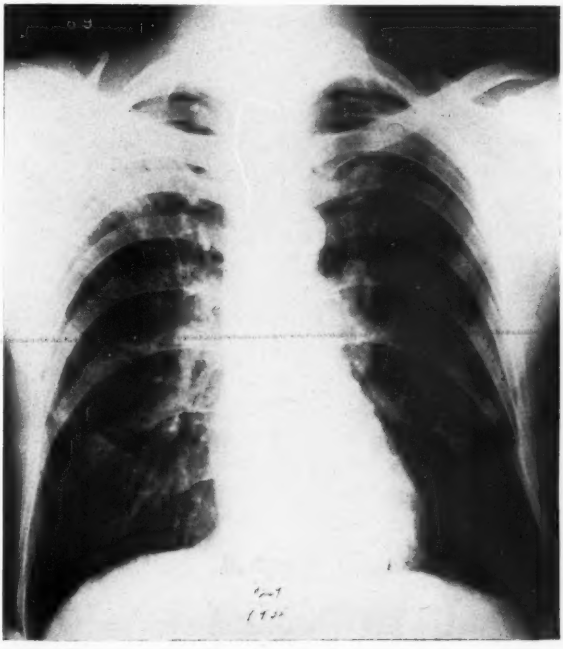

Fig. 1.—Case 1. Sept. 9, 1935. Infiltration in the upper third of the right lung.

At the time of his admission to the City Hospital on March 4, 1936, ten months after the onset of symptoms, it was obvious that the patient's condition had become progressively worse. He had developed persistent pain in the right shoulder and arm. Examination now revealed slight dullness over the right upper lobe, with decreased breath sounds and a few râles.

X-ray of the chest (Fig. 2) showed extension of the process in the right upper lobe. There was now a shadow of even density in the upper portion of the right lung, extending from the inner border of the first rib into the second anterior interspace and limited below by the interlobar septum. There was no evidence of cavitation. The right diaphragm was elevated as a result of the previous phrenic nerve paralysis.

Bronchoscopic examination showed no endobronchial tumor. Aspiration biopsy was twice negative for tumor cells. Bronchography showed no evidence of obstruc-

tion or bronchiectasis of the larger bronchi to the upper lobe. The smaller bronchi appeared to end sharply at the area of infiltration.

On April 2, 1936, after preliminary pneumothorax, exploratory thoracotomy under avertin and nitrous oxide-oxygen anesthesia was done through an anterior third interspace approach. The apex of the right lung was adherent to the chest wall by adhesions. The upper lobe was firm throughout. Because of the extensive adhesions, however, thorough examination could not be done. The remainder of the lung was free in the pleural space. The operative impression was carcinoma. Pneumonectomy was performed with individual double ligation and division of the structures in the hilum. Intercostal drainage was carried out.

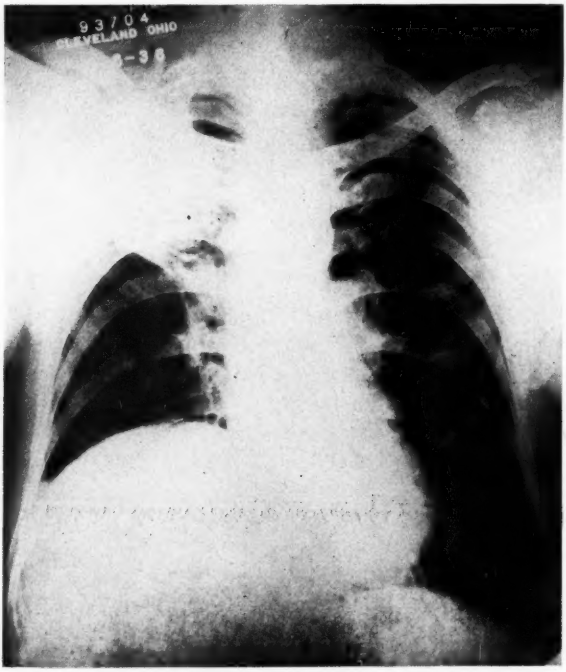

Fig. 2.—Case 1. March 6, 1936. Progression of the lesion which now appeared as a dense consolidation of the upper half of the right lung. The right diaphragm was elevated due to phrenic nerve paralysis. Pathologically, this condition proved to be chronic pneumonia with abscess formation.

The postoperative course was satisfactory except for the development of an empyema which required rib resection and drainage. A bronchial fistula persisted for many months. At present, four years after operation, the patient still has a small draining sinus. His general condition is good.

Pathologic examination of the specimen showed the upper lobe to be firm. On section there was extensive induration of the lobe, and in its posterior portion was a 3 cm. cavity through which passed a large pulmonary vein. The area about the cavity showed the greatest pneumonic infiltration, which extended along the bronchi to the hilum. Dissection of the bronchi revealed them to be patent with fibrotic walls and thickened granular and occasionally necrotic mucosal sur-

faces. The histologic diagnosis was organizing bronchopneumonia of the right upper lobe, abscess of the right upper lobe, acute and chronic bronchitis, and pleural fibrous adhesions.

Comment.—In this patient the impression of carcinoma of the lung was not supported by bronchoscopic study, lipiodol instillation, or aspiration biopsy. Nevertheless, the clinical picture strongly suggested its presence. The onset with irritative cough, the absence of any initial illness suggesting an acute pneumonia, the delayed diaphragmatic paralysis, the persistent shoulder and arm pain, the slow progressive course of ten months' duration, and the extension of the process roentgenologically without evidence of abscess or bronchiectasis were consistent with a bronchiogenic carcinoma. It was upon this basis that exploratory operation was undertaken.

The essential pathologic lesions, however, consisted of an extensive organized pneumonia of the right upper lobe, with a small abscess. The latter probably occurred as a late sequela of the pneumonic process since it was not visible in serial films taken over a period of many months.

The chronic pneumonias which are usually recognized clinically are considered to be the result of delayed resolution or organization of an acute lobar pneumonia or the chronic interstitial pneumonitis which takes place secondary to aspiration of foreign bodies, pulmonary atelectasis, bronchial obstruction, abscess, or bronchiectasis. Scadding,[10] however, has recently called attention to the fact that prolonged inflammatory lesions of the lung involving alveoli and interstitial tissues may occur as independent entities and are not necessarily preceded by any acute pneumonia. These chronic pneumonias are particularly important in differential diagnosis since their clinical course may contain little to indicate pulmonary inflammation. Although the onset may be with an acute illness, it is more frequently insidious. Hence the patient when first examined roentgenologically may already possess a well-developed pulmonary infiltration. Cough is an early manifestation, but in the absence of suppurative changes it is not accompanied by significant expectoration. Pyrexia of varying degree is generally present and is accompanied by loss of weight and strength. Spontaneous regression of the lesion may occur. Frequently, however, mild exacerbations of the inflammatory process take place, with eventual suppuration in the form of a localized abscess or bronchiectasis. Pulmonary hemorrhage and pain may occur. This symptomatology is common to bronchiogenic carcinomas and accounts for the confusing clinical problems which such insidious chronic pneumonias may present.

Despite observation of several similar cases, we have been unable to formulate any specific criteria by means of which the differential diagnosis between chronic pneumonia and carcinoma can be established with any degree of assurance. This has been particularly true of lesions situated peripherally and in the upper lobes, locations in which bron-

choscopy often fails to verify a clinical impression of bronchiogenic carcinoma. The physical examination is inconclusive, and the two conditions often present a similar roentgenologic picture. The chronic pneumonia appears as a unilateral lesion located in any portion of the lung field. It may be slowly progressive, and, if extensive fibrosis occurs, it presents the appearance of pulmonary atelectasis.

A significant diagnostic clue may be provided by the inability to demonstrate bronchial occlusion, although it should be remembered that not all bronchiogenic carcinomas necessarily result in occlusion of major bronchi. However, in patients presenting the symptomatology described, without evidence of an obstructive lesion, a diagnosis of bronchiogenic carcinoma should be approached with some degree of caution. In such instances every diagnostic measure available should be utilized. If these procedures are inconclusive, then the diagnosis of carcinoma and the decision concerning surgical intervention must be based solely upon the clinician's and surgeon's evaluation of the clinical picture.

CASE 2.—S. N., a 40-year-old white male, was admitted to Cleveland City Hospital on Nov. 17, 1936. He had been in good health until three months previously when he developed persistent pain in the right anterior chest, with cough productive of small amounts of odorless purulent sputum. Three weeks prior to admission several profuse pulmonary hemorrhages had occurred. He had lost 7 pounds in weight. The only point of importance in the past history was his statement that slight persistent cough had existed since an illness of unknown character in childhood. He had never noticed significant expectoration, nor had any acute pulmonary illness occurred.

Examination revealed only slight diminution of breath sounds and a few coarse râles in the region of the first and second anterior interspaces on the right side. The sputum was negative for tubercle bacilli.

X-ray (Fig. 3) revealed a triangular-shaped mass in the region of the right hilum, with its base anteriorly extending from the second to the fourth costal cartilages. This was interpreted as a carcinoma of the right upper lobe.

Bronchography showed no evidence of obstruction to the major bronchial branches. One small pool of lipiodol near the hilum was thought to represent a small cavity communicating with a secondary bronchus in the lower portion of the upper lobe. Bronchoscopy disclosed a thickened hyperemic upper lobe spur on the right. Blood and a small amount of purulent material emerged from the upper lobe bronchus. No endobronchial tumor was visible.

After the induction of pneumothorax, thoracoscopy revealed dense adhesions between the upper lobe and the anterior chest wall. No enlarged mediastinal nodes were seen.

On Nov. 21, 1936, the chest was explored through a right third anterior interspace approach. There were adhesions between the upper lobe and the anterior chest wall in the region of the third rib. After separation of the adhesions, a firm, fairly well-circumscribed mass was felt extending from the hilum into the upper lobe. No enlarged mediastinal nodes were visible. The operative impression was carcinoma. Pneumonectomy was performed with individual double ligation and division of the hilum structures. The chest was closed without drainage.

The patient subsequently developed a foul empyema with bronchial fistula for which rib resection and drainage were done. The empyema cavity was finally closed by a two-stage thoracoplasty in February and March, 1938. At the present time the patient is in good condition.

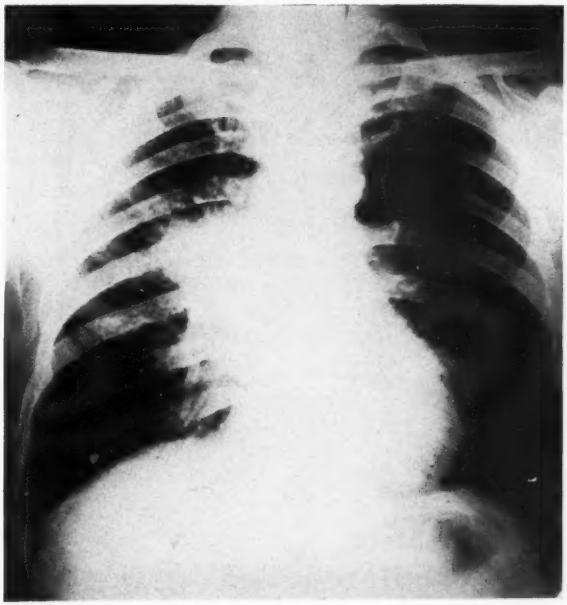

Fig. 3.—Case 2. Nov. 17, 1936. Mass in the region of the right hilum was interpreted as carcinoma of the lung but proved to be a localized area of multiple abscesses and bronchiectasis in the base of the upper lobe.

Pathologic examination of the lung showed a firm, irregularly circumscribed mass measuring 4 by 6 cm. in the lower portion of the upper lobe and extending into the middle lobe. On section this mass consisted of several abscess cavities from 0.5 to 2 cm. in diameter, containing small amounts of purulent material. The walls of the cavities were thick and fibrotic. The final histologic diagnosis was multiple abscesses of the lung with bronchiectasis, and acute and organizing pneumonia.

Comment.—It was recognized that the differential diagnosis in this case rested between a chronic inflammatory lesion such as abscess or bronchiectasis and a bronchiogenic carcinoma. The former impression was supported by the story of prolonged cough since childhood and the bronchographic demonstration of a small abscess cavity. The history of the present illness, however, was much more consistent with tumor. In a 40-year-old male the short duration of symptoms, with cough, persistent chest pain, hemorrhage, and weight loss, was considered typical of bronchiogenic carcinoma. The x-ray evidence of a mass in the region of the hilum also appeared characteristic. The lack of bronchoscopic confirmation was consistent with the frequency with which such examination is negative in upper lobe tumors.

Pathologic study, however, revealed the presence of multiple lung abscesses with bronchiectasis. Such an area of localized abscess formation in the lower portion of the upper lobe, producing the appearance of a mass in the hilum area, is unusual. This case illustrates, however, how closely such a chronic inflammatory disease of the lung may simulate the clinical and roentgenologic features of bronchiogenic carcinoma. Inasmuch as we were unable to exclude the presence of carcinoma with any degree of certainty, surgical intervention was advised. The patient's general condition was good, and he appeared to be a suitable operative risk.

CASE 3.—E. F., a 48-year-old white woman, was admitted to the Mount Royal Sanatorium on Feb. 17, 1938. Early in January, 1938, she developed a "cold," with a nonproductive cough and an occasional elevation of temperature to 101° F. During the succeeding five weeks the irritative cough persisted and finally became productive of small amounts of purulent odorless sputum. She had lost 11 pounds in weight. Shortly before admission a small hemoptysis had occurred.

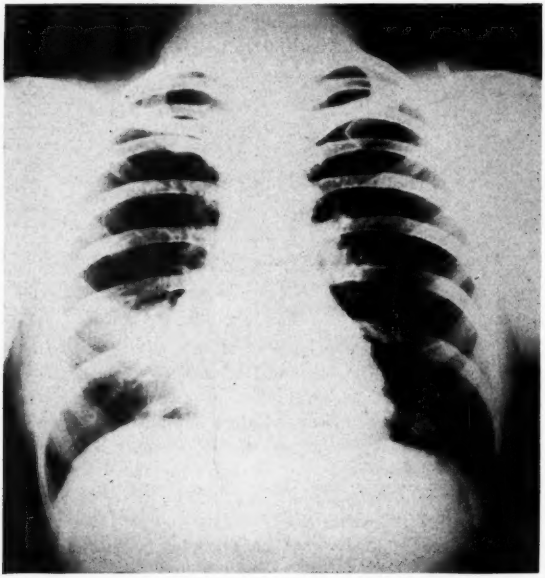

Fig. 4.—Case 3. March 14, 1938. Homogeneous area of increased density extending out from the lower pole of the right hilum. Pathologically this was the result of atelectasis of the middle lobe due to a tuberculous bronchial stricture.

Examination was essentially negative. The only abnormal chest finding was slight suppression of the breath sounds over the right middle lobe. Her temperature varied between 98° and 99.2° F. The white blood count was 8,800. Repeated examination of the sputum failed to reveal acid-fast bacilli.

X-ray of the chest (Fig. 4) showed a homogenous area of increased density, extending out from the lower pole of the right hilum with a feathery peripheral

margin. In the right lateral view (Fig. 5) this area was well defined and in the region of the right middle lobe.

Because of the possibility that an interlobar effusion might exist, aspiration was attempted in the region of the middle lobe, but no material could be obtained for biopsy examination.

Fig. 5.—Case 3. Right lateral view showing the well-defined atelectatic middle lobe.

Bronchoscopic examination on Feb. 25, 1938, showed the trachea, carina, and left bronchial tree to be normal. The right main stem bronchus appeared normal. The spur of the middle lobe was hyperemic. There was normal mucosa extending down for a distance of 5 mm. beyond the orifice. At this point there was a conical stenosis of the middle lobe bronchus which prevented the opening of the forceps within it. The bronchus was almost completely occluded by a small amount of pale, cellular material. The larger portion of the occlusion, however, appeared to be due to peribronchial infiltration. Aspiration revealed some pus beyond the obstruction, but a biopsy could not be obtained. However, from the appearance of the lesion, carcinoma appeared to be the most likely diagnosis.

Operative Note.—On March 18, 1938, under avertin, 60 mg. per kilogram, morphine sulfate gr. $\frac{1}{6}$, and atropine sulfate gr. $\frac{1}{150}$, cyclopropane anesthesia was started. A tracheal tube was inserted without difficulty. It was observed that the patient's respirations were depressed. Five cubic centimeters of coramine were given intravenously, with stimulation of respiration. An incision was made in the seventh interspace from the angle of the ribs to the anterior axillary line. The pleura was opened. The lung was partially adherent anteriorly in the region of the middle lobe.

The middle lobe was atelectatic, hard, and nodular. There was a small, firm nodule in the lower lobe. An adhesion between the middle lobe and the diaphragm was separated. At this point the patient ceased breathing, and despite various measures, could not be resuscitated. After death the right lung was removed for examination. The operative diagnosis was carcinoma of the lung and death from anesthesia.

Pathologic examination of the lung showed the upper and lower lobes to be essentially normal. The middle lobe was firm and noncrepitant. It sectioned with increased resistance. The cut surface was mottled and revealed firm, prominent lobulated masses. The smaller bronchial branches appeared dilated. The wall of the major bronchus was of varying thickness. The proximal portion showed a lumen of irregular contour varying from 2 to 5 mm. in diameter. The final histologic diagnosis was advanced organizing and recent bronchopneumonia, acute and chronic bronchitis and bronchiectasis, and caseous tuberculosis of the peribronchial lymph nodes. The scarred areas in the wall of the bronchus were considered typical of a healing or possibly a healed tuberculosis.

Comment.—The clinical diagnosis of bronchiogenic carcinoma was based upon the relatively short history of three months' duration, with symptoms of an irritative cough, hemoptysis, weight loss, and the bronchoscopic demonstration of occlusion of the right middle lobe bronchus. The roentgenologic appearance of atelectasis of the middle lobe was likewise consistent with carcinoma. This impression could not be proved by bronchoscopic or aspiration biopsy. However, it was the bronchoscopist's opinion that the larger part of the bronchial occlusion was the result of peribronchial infiltration and that, from the appearance of the lesion, carcinoma was the most likely diagnosis. It was thought unwise to observe the patient further to substantiate this, either by clinical change or by biopsy material which could be obtained should the tumor extend. The findings were judged sufficiently positive to warrant exploratory thoracotomy.

Pathologically the lesion consisted of an organizing bronchopneumonia and bronchiectasis secondary to a tuberculous stricture of the middle lobe bronchus. This case illustrates, therefore, another type of inflammatory process which may simulate carcinoma of the lung, namely, the inflammatory bronchial stricture.

Bronchial occlusion and atelectasis have always been considered important diagnostic criteria of bronchiogenic carcinoma inasmuch as the majority of such tumors arise in connection with the major bronchi or their eparterial and hyparterial branches.[7] In certain instances, however, bronchoscopic visualization of the tumor is impossible since the bronchus of origin need not necessarily be occluded by extension of the carcinoma into the lumen. Occasionally stricture occurs by peribronchial infiltration of the neoplasm, without apparent ulceration or invasion of the mucosa. In such cases biopsy of the mucosa may sometimes reveal the presence of tumor cells.

During the past few years considerable attention has been devoted to inflammatory lesions of the bronchus which may produce a similar stenosing effect. Tuberculosis, for example, is frequent and of great significance.[3] The appearance, varying from the granulomatous and ulcerative lesion to the fibrous stricture in the healing stages, may closely resemble bronchiogenic carcinoma. Obstruction is common with atelectasis, chronic pneumonitis, bronchiectasis, and abscess formation similar to the phenomena encountered in pulmonary carcinoma.

In such obstructive lesions the differential diagnosis rests largely on the bronchoscopic examination. Such studies, however, are not always conclusive. The tumor itself may not be visualized, or material removed for biopsy may show only nonspecific inflammation of the bronchial wall. In such cases considerable reliance must be placed upon the bronchoscopist's interpretation of the findings. Bronchography is of little value since it merely reveals the presence of stenosis, but fails to elucidate its etiology.

If the inflammatory stricture is tuberculous, sputum examination may be of assistance. In the earlier stages active parenchymal lesions are usually present so that the finding of tubercle bacilli is of diagnostic value. In the healed fibrotic stages of bronchial tuberculosis, however, tubercle bacilli are often absent from the sputum. The case described belonged to this group. It was unusual in that no parenchymal disease could be demonstrated, and the bronchial lesion probably arose by extension from adjacent caseous peribronchial lymph nodes. Similar cases of pneumonectomy for tuberculous bronchial stenosis simulating carcinoma are reported by Crafoord.[2]

An example of nontuberculous bronchial stenosis is given in the following case report.

CASE 4.—S. N., a 55-year-old white male, was admitted to the Cleveland City Hospital on June 2, 1937. Five months prior to admission he had developed an irritative nonproductive cough which had become progressively worse. The cough was associated with a knifelike pain in the right anterior chest. An 11-pound weight loss had occurred. The onset of symptoms was gradual, and at no time had the patient been acutely ill.

Physical examination revealed decreased expansion of the right chest, with diminished breath sounds over the right lower lobe. The temperature varied from 37 to 38° C. The white blood cell count was 7,800 cells per cubic millimeter. The sputum was negative for tubercle bacilli.

X-ray (Fig. 6) on May 26, 1937, showed dense infiltration of the lower third of the right lung, extending outward from the right hilum. The cardiac shadow was slightly displaced to the right, and the interspaces at the base appeared narrowed. The findings were considered consistent with the clinical impression of bronchiogenic carcinoma.

Bronchoscopic study on June 7, 1937, showed some firm, reddish-gray tissue obstructing the right main bronchus. This was removed for biopsy. The microscopic diagnosis was "bronchial mucosa the seat of chronic inflammation." Bronchoscopy

was repeated June 16, 1937. The right main stem bronchus in its inferior portion was slightly fixed. Just below the upper lobe orifice the bronchus was slightly stenotic, and its walls were smooth and hyperemic. A small amount of greenish-yellow secretion arose from the lower lobe. The middle lobe orifice could not be visualized and appeared to be occluded by a firm peribronchial growth. Biopsy was difficult to obtain because of the firmness of the bronchial wall, but several particles were taken. These were reported as "bronchial mucosa the seat of a well-differentiated squamous carcinoma and acute inflammation."

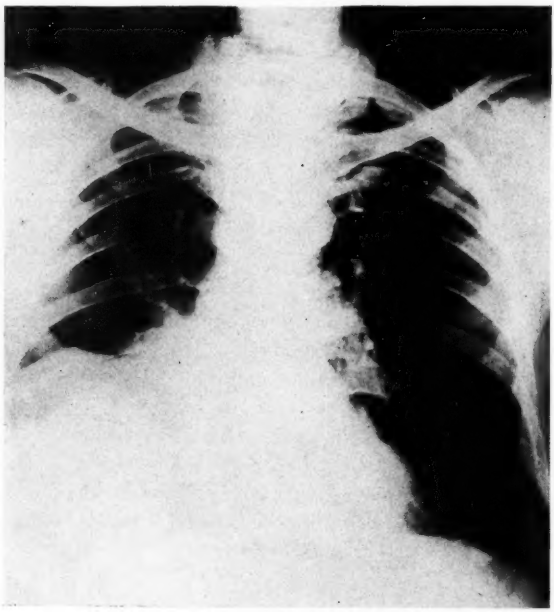

Fig. 6.—Case 4. May 26, 1937. Area of consolidation in the lower third of the right lung field was interpreted as a bronchiogenic carcinoma. This was proved to be due to atelectasis of the middle lobe following an obliterative bronchitis of the larger and smaller bronchial branches.

After preliminary pneumothorax, right total pneumonectomy through an anterior incision was performed on June 26, 1937. The middle lobe appeared entirely collapsed, the lower lobe was adherent to the diaphragm, and the upper lobe to the costovertebral gutter. There were no palpable mediastinal nodes. Death occurred ten days after operation from an empyema in the postpneumonectomy space and a bronchopneumonia in the contralateral lung.

Pathologic examination showed extensive pleural thickening over the right middle and lower lobes. The middle lobe was firm and granular, and it appeared to be the seat of a diffuse consolidative process. The upper and lower lobes were normal. The bronchial mucosa was intact, without evidence of bronchial obstruction. Histologically there was atelectasis of the right middle lobe. This was chronic in nature since the alveolar walls were thickened and fibrotic as were the smaller blood vessels. The source of the atelectasis was to be found in a severe chronic bronchitis affecting the larger and smaller branches of the middle lobe. Many of the bronchi appeared almost obliterated by collars of dense fibrotic connective tissue. There was, in addition, extensive squamous metaplasia of the bronchial mucosa.

Careful examination of the entire lung removed at pneumonectomy, as well as autopsy examination, failed to reveal any evidence of carcinoma.

Comment.—Pneumonectomy was recommended because the clinical and x-ray evidence of tumor was supported by the pathologist's diagnosis of carcinoma on the material removed by bronchoscopic biopsy. The latter report obviously was in error inasmuch as comparison of the biopsy sections with the microscopic sections of the excised lung left no doubt that the metaplastic bronchial mucosa was mistaken for squamous carcinoma.

The fundamental nature of the inflammatory process in the right middle lobe could not be elucidated. It was probably of nonspecific character since neither tuberculosis nor syphilis could be demonstrated. The production of an obliterative bronchitis, however, was responsible for atelectasis of the lobe, which simulated the picture of a bronchiogenic carcinoma.

DISCUSSION

In the management of these chronic inflammatory lesions of the lung, two problems have been encountered.

The first concerns the justifiability of exploratory operation in the absence of a positive diagnosis. In the past the recognition of a bronchiogenic carcinoma was largely of academic interest since little could be accomplished therapeutically. At present, however, the feasibility of surgical treatment renders accurate diagnosis of practical importance. To delay operation in every patient until the diagnosis is definitely established means that cases otherwise suitable for surgical treatment may become inoperable because of local extension of the tumor or the development of metastases. Despite the widespread interest during the past few years in carcinoma of the lung, the reported series of cases indicates that only a small number of the persons operated upon have been amenable to successful surgical therapy. Certainly the number of patients to whom surgery may be offered in the future will increase only with earlier recognition of the disease. However, it is in the early stages or in the presence of lesions simulating carcinoma that absolute diagnostic proof may be lacking. That occasional errors will occur under these circumstances is obvious. It is our opinion, nevertheless, that in individual instances, if the patient's condition permits, surgical intervention is justified if the history and roentgenologic findings indicate tumor even though bronchoscopic and biopsy findings are not confirmatory. The cases recorded above were in this category.

A further serious problem in the surgical management of these patients has been the difficulty in determining the exact character of the disease at exploratory operation. In the cases described it was impossible to clearly differentiate between carcinoma and inflammatory dis-

ease, even by direct inspection and palpation of the lung. The gross characteristics of tumor were simulated by the fibrosis and pneumonic infiltration of the inflammatory process which appeared as a firm, irregular, and nodular mass within the lung. Particularly confusing were those lesions which, because of their location or because of the medial extension of the indurative process, suggested the presence of a mass in the region of the hilum. Likewise, in the two cases of inflammatory bronchial stenosis the atelectatic lobes suggested the typical gross findings of a bronchiogenic carcinoma.

Acessory observations are of little assistance. Enlargement of mediastinal lymph nodes is unreliable inasmuch as such enlargement occurs frequently in various inflammatory lesions. Biopsy of lymph nodes for frozen section study may occasionally be of aid if the excised nodes happen to contain neoplastic tissue. Direct biopsy of a pulmonary mass by transection of the lung has not been extensively advocated thus far since serious pleural infection may result if abscess or bronchiectasis is present. Such a procedure may perhaps have its place in those occasional instances in which the clear-cut demonstration of an inflammatory lesion would indicate the performance of lobectomy rather than total pneumonectomy. Direct biopsy, however, does not in itself afford complete assurance that tumor is absent. Bronchiogenic carcinomas are so frequently accompanied by various inflammatory lesions that even such a biopsy may occasionally fail to show neoplastic tissue.

Although no criteria have thus far been described for the correct recognition of these lesions at operation, further accumulated experiences in surgical therapy may result in greater accuracy in differential gross diagnosis, a point to which Overholt has called attention.[8]

Diagnostic and therapeutic problems of the character recorded above have received relatively little attention in the literature on bronchiogenic carcinoma other than in scattered reports.[1, 2, 8, 9, 10] To us, they have been of great interest because of the diagnostic difficulties presented. The real test of diagnostic acumen, after all, consists not only in the determination of the percentage of bronchiogenic carcinomas correctly recognized, but also in the opposite correlation, that is, the number of cases diagnosed as carcinoma clinically and roentgenologically in which some other lesion is actually found to be present. With the greater utilization of surgery in the treatment of carcinoma of the lung, chronic inflammatory lesions of the type described will undoubtedly assume increased diagnostic importance.

SUMMARY

Four cases are described in which the clinical and roentgenologic findings of bronchiogenic carcinoma were simulated by various inflammatory diseases of the lung.

It is pointed out that the usual investigative procedures may be of little aid in establishing the differential diagnosis.

The justifiability of exploratory thoracotomy in the absence of a positive diagnosis and the difficulty in the recognition of the nature of the pulmonary lesion at operation are discussed.

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CONTROL OF HEMORRHAGE IN INTRAPLEURAL PNEUMOLYSIS

The Indication for This Operation in the Tropics

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HEMORRHAGE during intrapleural pneumolysis (Jacobaeus operation) is not a very frequent, but a very disagreeable, complication. This is best illustrated by the fact that one of the most experienced operators, G. Maurer of Davos, has devised an ingenious apparatus (combined diathermy and cautery) in order to prevent hemorrhage and to allow operating within the chest wall as far away as possible from the lung. Theoretically, his idea is certainly sound; but how great is the actual advantage it offers? Is it possible to operate at a considerably greater distance from the lung when using diathermy instead of the cautery?

Adhesions to the mediastinum or to the big blood vessels need not be considered, for these cannot be "shelled out" with any method; the difference between the two methods can appear only in operating upon adhesions situated on the thoracic wall. These are attached either to ribs, or to the tissue of the intercostal spaces, or to both. The distance between the costal pleura and the rib is not even one millimeter; in this region it is impossible, therefore, to operate more than one millimeter outside the pleura by any method. Only if the adhesion, by a lucky accident, is attached exclusively to the tissue of an intercostal space, is it possible to operate at a greater distance. But adhesions which are no broader than an intercostal space generally present little or no difficulty. The difficulty lies with broad-based adhesions "the size of a wrist or more," such as have been successfully operated upon by Maurer and others; and such adhesions are necessarily attached to at least one rib. It seems somewhat doubtful, therefore, whether operators, when "shelling out" adhesions, really work, as a rule, at a considerable distance outside the pleura; if so, they must come into frequent collision with the ribs, an accident I have not found recorded, although it can certainly happen and has been experienced by myself more than once.

These remarks are not intended to disparage the merits of Maurer's apparatus. I readily believe that, when following the customary technique, hemorrhages are more easily controlled with diathermy than with the cautery. I have had Maurer's electrodes always ready for use during my last 200 Jacobaeus operations, but I have never used them. It seems that hemorrhages can be controlled easily with the cautery alone by using a special technique, based upon the following facts:

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1. Hemorrhages during the Jacobaeus operation nearly always come from vessels of the thoracic wall; surgically speaking, these are small hemorrhages, which are dangerous only when they continue for a considerable time. Without doubt, they have to be safely stopped, but there is no hurry about it.

2. It is frequently recommended to stop these hemorrhages by touching the bleeding spot with the incandescent cautery. This, in my opinion, is exactly what one ought not to do. The cautery is immediately cooled by the blood and is covered with a crust which is a bad conductor of heat (and electricity). It becomes impossible, therefore, to estimate rightly how strong the current must be made to coagulate the bleeding tissue. If it is too strong, the tissue is only severed; if it is too feeble, there is no effect, except that the cautery sticks to the tissue and, when withdrawn, is likely to tear it. In both cases the hemorrhage may be increased instead of stopped.

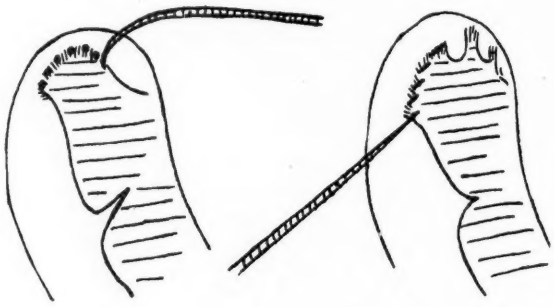
I act in the following manner. Without switching on the current, and thus with the cold cautery, the circumference of the bleeding spot is systematically touched under slight pressure at a distance of about 3 mm. from the site of the hemorrhage. As soon as the cautery presses upon the vessel which leads to the bleeding spot, the hemorrhage stops, or at least is greatly diminished. Then, the current is switched on, and the tissue is coagulated, together with the hidden blood vessel. One can safely use a rather strong current (about 15 amp. with Kremer's cautery); then the current is switched off and the pressure released, but the cautery remains on the tissue. In case the hemorrhage starts afresh, slight pressure is applied again, and the tissue is coagulated more deeply. If the bleeding stops, the cautery is slowly withdrawn; in doing this, the current must be switched on again, and sometimes increased (ca. from 16 to 17 amp.), in order to detach the cautery smoothly from the tissue without tearing it. For safety's sake, several spots in the vicinity may be coagulated in the same manner; eventually the spot of the hemorrhage, no longer bleeding, is singed.

During my last 200 Jacobaeus operations hemorrhage occurred eleven times. (Two of these were small arterial hemorrhages.) Each time I was surprised at the ease with which the hemorrhage could be stopped in the manner described. A postoperative hemorrhage, and that not dangerous, has been observed in only one of these cases.

Prevention, however, is better than cure. Is there no way to avoid these hemorrhages altogether or nearly so? I think that much can be done to prevent them by using a technique which has been suggested to me by an accidental observation. A native boy, about 2 years old, was brought to me for treatment. He had on the right cheek and upper lip an hemangioma cavernosum about the size of a silver dollar, a bluish-red, bulging tumor, which also protruded into the oral cavity. Remembering how my teacher in surgery, Professor von Hochenegg of Vienna, used to operate upon such tumors, I burnt a number of holes, more than thirty, into it, partly from the outside and partly from within the mouth. I used the same instrument as was used for the Jacobaeus operation, but with a current of considerably greater strength, from 20 to 22 amp. (In the Jacobaeus operation, I do not use more than 18 amp.) The operation was done in several stages; scarcely a drop of blood was lost during the operation and none was lost after it. The tumor eventually was changed into a flat, inconspicuous scar. An hemangioma cavernosum

is much richer in blood vessels than any pleural adhesion; consequently, it ought to be possible to operate upon adhesions without danger of hemorrhage by using a similar technique. My experience indicates that this can indeed be done by proceeding in the following manner:

If hemorrhage seems possible (as is virtually always the case, except in thin transparent adhesions), a row of holes of about 5 mm. depth is burned into the base of the adhesion, using a rather strong current (ca. from 14 to 17 amp.); one lets the cautery "sink" into the tissue with scarcely any pressure and without moving it sideways; the distance between the holes is about 4 mm. This procedure coagulates blood vessels leading to the adhesion, as well as the tissue between the holes. After a few minutes (during which time other parts of the adhesions can



a. *b.*

Fig. 1.—Adhesions with "coagulation holes."

be dealt with), the tissue between the holes is burnt through. Then another row of holes is burnt into the new border line between the adhesion and the chest wall, and so on. (It goes without saying that the chest wall is anesthetized before, as is always done when big adhesions have to be shelled out.) Of course, the technique varies with the local conditions; not infrequently, for instance, the cautery has to be applied more or less parallel to the border line of an adhesion, in which case the "coagulation holes" are overlapping each other (Fig. 1*b*). But the principle always remains the same. By systematically "puncturing" the adhesion base with the strongly incandescent cautery, blood vessels and tissue are firmly coagulated before being severed. I employ the same method when dealing with adhesions long enough to be divided at a distance from the chest wall; in that case, a number of holes are burnt right through the adhesion, or, if it is too thick for that, these are burnt to a certain depth. Then the tissue bridges between the holes are severed.

According to my experience, this method is not only safer but also a great deal quicker than shelling out or dividing adhesions in the ordinary manner, which allows only the use of a rather feeble current if hemorrhage is to be avoided. By the described technique, it becomes possible to operate upon very extensive adhesions "the size of a wrist or more" at a single stage without the danger of hemorrhage.

But here arises a totally different question. Is it advisable to perform such extensive Jacobaeus operations? I am rather doubtful about that. Adhesions are of tuberculous origin and have frequently been

found to contain tubercle bacilli. How far these may have penetrated toward the chest wall is impossible to ascertain. It is equally impossible to know how far the lung extends toward the chest wall in the interior parts of a thick adhesion, and, as pointed out before, it is, in the case of such broad-based adhesions, utterly impossible to work throughout at a considerable distance (more than one millimeter) outside the pleura. More likely than not, the operation is done in tuberculous tissue. That infections of the pleural cavity are not more frequent may be due to the fact that most of the bacilli in the operative field are killed, or at least damaged by heat, and that, as a rule, only a few tubercle bacilli do not produce serious general pleurisy, much less empyema. But, the more extensive the adhesions severed, the greater the probability that a considerable number of bacilli enters the pleural cavity, either during the operation or later when the sloughs are cast off. There is no doubt that serious pleurisy and empyema are far more frequent after extensive difficult Jacobaeus operations than after limited simple ones, and that their consequences (toxic effects, obliteration of pleural cavity, etc.) have annihilated the benefit of more than one operation which, technically, had been a complete success. On the contrary, a partial thoracoplasty supplementing artificial pneumothorax is a comparatively small operation, especially when performed through an axillary incision. Generally it will be an apical thoracoplasty, involving resection of from three to five of the uppermost ribs, an operation nearly free of risks. In my opinion, a small thoracoplasty is much less dangerous than an extensive Jacobaeus operation and, therefore, is to be preferred.

This little restriction scarcely diminishes the immense value of the Jacobaeus operation. Its value is even greater in the tropics than in Europe and America, because the patients here nearly always have adhesions when they apply for treatment, and scarcely ever can they afford prolonged stay in the hospital or sanatorium, but have to be treated as outpatients after a short time. In my practice it has become a matter of routine to operate upon adhesions as soon as possible—generally within the first ten days after inducing artificial pneumothorax, and not infrequently on both sides within the first month of treatment. As a matter of fact, this is done, not only for economic reasons, but also because I am fully convinced that, in the great majority of cases, the sooner cavities are closed, the better. I do not think that Jacobaeus operations performed at such an early stage present any greater difficulties than those done later on; adhesions, it must be remembered, are stretched, not only after pneumothorax, but before as well (through the respiratory excursions of the lung). Operation at an early stage always shows a perfectly transparent pleura, an advantage not to be despised.

The possibility of hemorrhage may be somewhat greater than after prolonged stretching of adhesions, which, by the way, also has serious drawbacks; but, by using the technique I have just described, the danger of hemorrhage is minimized.

CONCLUSIONS

Pleural adhesions in artificial pneumothorax should be severed as soon as possible, especially in the tropics.

By using a special technique, hemorrhage can be prevented almost with certainty, and should it occur, it can be stopped safely and easily.

Very extensive Jacobaeus operations present the danger of serious infection of the pleural cavity, and it is better if partial thoracoplasty is substituted.

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AN EFFECTIVE METHOD FOR THE CLOSURE OF CANNULA OPENINGS FOLLOWING INTERNAL PNEUMOLYSIS

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THE postoperative escape of air, due to the unsatisfactory closure of the cannula openings by superficial suture and pressure dressing, is a troublesome complication of internal pneumolysis.

This leakage of air often results both in the development of a painful subcutaneous emphysema and in a partial or total loss of the pneumothorax. The latter may be especially disastrous. The coagulated end of the recently severed adhesions, if allowed to come into contact with the chest wall, may adhere and become permanent.

An effective way of preventing this leakage of air is to close the cannula openings by means of a through-and-through suture. This will tightly close the opening in the parietal pleura and thus prevent the escape of air from the pleural space into the soft tissue.

The following procedure which has been developed for performing this closure has proved so satisfactory that it seemed worth while to describe it.

The technique requires the use of three cannula openings. If the operator is using the two-piece instrument, an additional third opening must be made. If a one-piece instrument is being used, two additional openings must be made. It will be found convenient if the openings are so placed as to form an equilateral triangle.

The operation of intrapleural pneumolysis having been completed, the additional cannula is inserted and the following procedure is performed. Through one cannula the thoracoscope is inserted for visualization of the intrapleural part of the procedure. Through another cannula a 9- or 11-inch Mathieus grasping forceps is introduced. An assistant then introduces a Reverdin needle, with suture about 1 cm. lateral to the third cannula.

With the physician working intrapleurally under the guidance of the thoracoscope, the suture is grasped with the Mathieus forceps and the Reverdin needle is then released and withdrawn. The latter is then reintroduced on the other side of the cannula, the suture is placed in the slot by means of the Mathieus forceps, and the Reverdin needle is locked and again withdrawn, bringing the suture with it.

The two ends of this through-and-through suture are left long, as they cannot be tied until the sutures have been placed for all three of the cannula openings.

The instruments are rotated through the three cannulas, and the above procedure is repeated respectively until sutures have been placed across all three openings.

Then, during observation of the closure through the thoracoscope, one cannula is removed, and the suture is tied tightly by an assistant. The second wound is tied under observation in a like manner. The patient is then requested to take a deep breath, and the third cannula is removed and the final suture tied.

The wounds are carefully dressed, and the sutures, which are dermal, are removed on the fourth or fifth day. So far, we have not had an appreciable escape of air, which has prevented the frequent refills heretofore necessary to maintain pneumothorax.

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THE CLINICAL MEASUREMENT OF PULMONARY ELASTICITY

A Comparison of the Methods of Christie and McIntosh and of Neergaard and Wirz*

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INTRODUCTION

DURING the pursuit of certain studies of the nature of pulmonary emphysema it became evident that some method of determining pulmonary elasticity would have to be employed. That such a measure was necessary was impressed upon the author when it was realized that a loss of elasticity by the lungs was the most typical physiologic characteristic of emphysema and the measure by which, short of pathologic examination, it ultimately must be differentiated from other conditions. A clinical method by which this phenomenon of elasticity, the most characteristic quality of lung tissue, can be measured fairly accurately should be of value to all those interested in the study and treatment of pulmonary disease.

Certain indirect effects of lung elasticity, such as the elastic recoil of dead lungs when the thorax is opened and the change of intrapleural pressure occurring with respiration, have been appreciated for a relatively long time, but attempts to measure the elasticity itself and correlate it with clinical conditions have been rare. This paper deals with a consideration of certain measures of elasticity determined for twenty-three patients in the University of Minnesota Hospitals.

PRELIMINARY STUDIES ON DEAD LUNGS

James Carson, in 1820, first noted that, if the thoracic cavity of an animal were opened after death, the lungs collapsed with an appreciable force. Carson measured this force of elastic recoil of the dead lungs in various animals by measuring the height of a column of water which would be sustained by the air forced out through the trachea. Donders, in 1853, measured the same force in human cadavers by attaching a water manometer to the trachea and then opening the thorax. On the basis of these measurements he estimated that the intrapleural pressure in the living person was about –10.0 cm. of water. Later Liebermeister and Romanoff distended the lungs of cats and calves with pressures as high as 30 cm. of water. By these experiments it was shown that the volume of the lung increased but little

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with pressures below 10 and over 20 cm. of water. In the middle range of pressure (between 10 and 20 cm.) the increase in volume of the lung was quite large for the increase of pressure.

The importance of these researches was questioned by Van der Brugh, who, on the basis of his experiments with the lungs of animals before and immediately after death, thought that changes took place in the immediate post-mortem period which prevented the use of results obtained on dead lungs in explaining living phenomena.

It had not been demonstrated, however, that the elasticity of dead lungs could not be determined sufficiently accurately to afford a basis of comparison between two or more post-mortem specimens. If such a comparison could be made, it would be of considerable value in the study of pulmonary diseases in the experimental laboratory as well as at autopsy. Consequently, an investigation of the elastic qualities of dead lungs removed intact from eleven cadavers and ten sacrificed dogs was made. These lungs were distended repeatedly in a specially constructed hermetically sealed hood under controlled conditions. The results showed, however, that the elastic properties of dead lungs varied over such a wide range, both with regard to different specimens as well as with regard to repeated experiments on the same specimen, that no worth-while conclusions seemed justified. These investigations were, therefore, abandoned and the clinical estimation of pulmonary elasticity in the living lung was attempted.

STUDIES ON LIVING LUNGS

Measures of Elasticity.—By definition, elasticity is taken to mean that property of a substance which tends to cause it to resume its former bulk or shape after distortion by an external force. Any measure of elasticity must, therefore, concern itself with two factors: (1) the force producing distortion, and (2) the amount of distortion produced by this force. With reference to the lungs, the force producing distortion must be arrived at through a consideration of the changes in the intrapleural pressure occurring with respiration. The distortion produced by this force must, on the other hand, be determined by evaluating the changes occurring in the volume of the lungs during respiration. That both of these factors must be determined simultaneously is self-evident. The ratio between these two factors serves well enough for the comparison of the elasticity of lungs of about the same size, such as those of adults, and can be expressed as follows:

$$\text{Measure of elasticity} = \frac{\text{Change in intrapleural pressure occurring with a given phase of a given respiration}}{\text{Increase or decrease of the lung volume occurring with a given phase of a given respiration}}$$

A more accurate measurement, however, must be used if it is desired to compare the elasticity of lungs of different sizes, such as those of an infant and of an adult. Under these circumstances the true modulus of

elasticity must be determined, in which the relative increase or decrease in the size of the lung produced by a distorting force is taken into consideration. This measure is, therefore, expressed as follows:

$$\text{Modulus of elasticity} = \frac{\text{Change in intrapleural pressure occurring with a given phase of a given respiration}}{\dfrac{\text{Increase or decrease of the lung volume occurring with a given phase of a given respiration}}{\text{Total volume of the lung}}}$$

Attempts to measure the elasticity of the lungs in the living animal or patient by direct methods are few in number and of relatively recent date. Cloetta, in 1913, with a plethysmograph studied the elastic properties of the lungs of living cats, dogs, rabbits, and monkeys. The distention and deflation curves which he constructed from these experiments followed straight lines within the range of pressures which he considered to be normally present in the living animal. On the basis of these results, Cloetta concluded that the elasticity of the lungs of the normal living animal within the ordinary range of distention was perfect.

Method of Christie and McIntosh.—On the basis furnished by Cloetta's experiments with animals, Neergaard and Wirz as well as Christie and McIntosh have suggested methods of measuring the elasticity of the lungs of living patients. Christie and McIntosh registered simultaneously the volume of tidal air and the intrapleural pressure. They considered that the variation in intrapleural pressure furnished an adequate measure of the force producing distortion and that the volume of the tidal air was the distortion produced. If, therefore, the maximum change in intrapleural pressure between expiration and inspiration as measured in centimeters of water be divided by the volume of tidal air in 100 c.c. corresponding to that change in pressure, the result would be a measure of elasticity which they called the "unit of pulmonary distensibility." Christie and McIntosh felt that, while this value varied considerably among various persons, it was remarkably constant in the same person and was independent of changes in the tidal air.

Variation in the unit of distensibility among different persons is to be expected since, among other things, the size of the lungs varies. To correct for this variation and furnish a normal standard of comparison between persons, it was proposed to adopt another value, "the coefficient of distensibility," which would not vary with the size and stature of the person. Since the depth of an ordinary breath was found by Christie to be approximately 20 per cent of the functional residual air despite considerable variation in actual volume, the force necessary to produce this amount of distention in the lungs could be used as a measure of elasticity. "The coefficient of distensibility" was, therefore, defined as the change in the intrapleural pressure which accompanies an ordinary inspiration.

Method of Neergaard and Wirz.—Neergaard and Wirz criticized Christie's and McIntosh's method because it did not allow for the determination of the intrapleural pressure at those points in the respiratory cycle when the elastic forces within the lungs and thorax were in static equilibrium. To be sure, an equilibrium of forces was always present, but, because of the movement of air in and out of the lungs, this equilibrium was one of both static and dynamic forces except at the exact instant of change in the respiratory cycle from expiration to inspiration and from inspiration to expiration. At these points no air was moving in the bronchial tree,

and the elastic forces were in static equilibrium. The measure of true lung elasticity could, therefore, be arrived at only by determining the difference in intrapleural pressure between two consecutive phase-change points and considering this as the force producing distortion. The tidal air corresponding to this phase of respiration would then be the measure of distortion produced, and a factor of elasticity could be computed.

To determine the above values, Neergaard and Wirz registered simultaneously, by means of optical manometers on a moving photographic film, the intrapleural pressure and the velocity of the air flow in the trachea. From the curves thus produced, the phase-change points on the intrapleural pressure curve were located, the volume of tidal air was calculated, and a "factor of elasticity" was determined.

If it was desirable to take into account the variation in the size of the lungs among different persons, Neergaard and Wirz advised that the volume of the lung in expiration, which was assumed to be always the same in a single person, be computed from an x-ray plate of the chest by the formula proposed by Rohrer.*

Theoretically these ideas appear to be sound; yet if one is to judge from Neergaard's own publications and other reports in the literature, the method has been used far too little in actual practice to be accepted without question. One wonders also if the refinements and elaborate equipment which the method requires are really necessary for practical purposes.

METHOD EMPLOYED

In the experiments reported in this paper the elasticity of the lungs of three groups of patients has been studied by simultaneously employing both of the methods described above. The intrapleural pressure, the velocity of air flow through the trachea, and the volume of the tidal air have been recorded for the duration of several complete respiratory cycles. From the data thus obtained, the elastic factors of Neergaard and Wirz and of Christie and McIntosh have been compared for consistency and practical value.

The subjects for these experiments consisted of (1) a control group of patients on the surgical service of the University of Minnesota Hospitals, who, so far as could be determined from history and physical examination, had no pulmonary disease; (2) a group of carefully selected patients, who, on the basis of history, physical examination, or x-ray examination of the chest, were thought probably to have pulmonary emphysema; and (3) a small group of patients with miscellaneous conditions. It was hoped that a comparison of the results in these groups, besides furnishing a check on the value of the methods used to measure the elasticity, might give some worth-while information concerning the elastic behavior of the lung in emphysema.

TECHNIQUE OF EXPERIMENTS

Registration of Intrapleural Pressure.—The intrapleural pressure was recorded on sensitized bromide paper by creating a small pneumothorax on one side of the chest through a No. 17 gauge needle inserted into the pleural cavity and then connecting this needle to an optical manometer. In the first few experiments a plain

*Rohrer's formula to determine the volume of the lungs from x-ray films of the chest:

$$J = K \frac{Fa(Fb)}{h}$$

K = a constant (0.9).
h = distance in centimeters from highest point of the diaphragm to the apex of lung.
Fa = sagittal projection of lungs in centimeters.
Fb = transverse projection of lungs in centimeters.

needle with a short bevel was used. A great deal of trouble, however, was encountered in obtaining an uninterrupted registration of pressure because of the lung's impinging upon the point of the needle. Therefore, a side opening the same size as the lumen of the needle was made in the side wall just back of the point, and this eliminated most of the technical difficulty. With the plain needle it was always necessary to produce a pneumothorax of from 80 to 100 c.c. before there was any likelihood of obtaining a good registration. After making the side opening, however, a pneumothorax of from 40 to 60 c.c. was usually all that was required. All measurements were made with the patient reclining on the side with the arms raised. The needle was inserted through the seventh or eighth intercostal space at the highest point of the side of the chest that was uppermost. One per cent novocaine was used to infiltrate the chest wall at the site of puncture.

Registration of Velocity of Air Flow in the Trachea.—The registration of the velocity of the air flow in the trachea was made by having the patient breathe through a pneumotachograph. This instrument, first described by Von Fleisch, works on the principle of Poiseuille's law.* It consists of ninety metal tubes, 20 cm. long, each with a lumen of 2 mm. These tubes are soldered together so that no air can pass between them. To one end is fastened a slightly tapered mouthpiece, the smallest diameter of which is 2.5 cm. To four of these tubes making up the body of the instrument, pairs of short vertical tubes of the same size are joined with varying distances between them. In one pair the distance is 18 cm.; in a second pair, 9 cm.; in a third, 4 cm.; and in the fourth, 1.5 cm. Any one of these pairs of tubes, when connected to a differential optical manometer, records on sensitized bromide paper the velocity of air passing through the pneumotachograph. The greater the distance between the vertical tubes used, the greater will be the excursion of the curves recorded. A diagram of the apparatus is shown in Fig. 1.

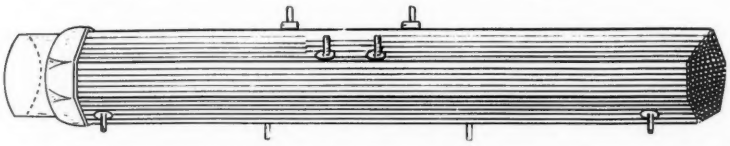

Fig. 1.—Pneumotachograph of Von Fleisch. On the basis of Poiseuille's law, if any pair of the short vertical tubes be connected to a differential manometer, the velocity of the air flow through the apparatus will be recorded.

As used in this paper, the pneumotachograph registration produced a continuous series of curves fluctuating back and forth across a base line which also represented atmospheric pressure for the intrapleural pressure registration. The area of the space enclosed by the base line and pneumotachograph curves is directly proportional to the tidal flow of air in and out of the trachea. The height of curve with respect to the base line is directly proportional to the velocity of the air flow. The points at which the curve crosses the base line are the phase-change points at which, theoretically, all elastic forces in the chest are in static equilibrium.

Registration of the Volume of Tidal Air.—The tidal air was measured by connecting the distal end of the pneumotachograph to the spirometer of a Benedict-Roth metabolism apparatus. If the soda-lime cylinder be removed from this apparatus, the attached kymograph registers directly the volume of tidal air. In a few of our experiments the soda-lime cylinder inadvertently was not removed, and consequently the expiratory volumes as recorded by the kymograph were in error by the

*Poiseuille's law states that the quantity of air flowing through a rigid tube is proportional to the difference in pressure between any two places in the tube.

amount of carbon dioxide absorbed by the soda lime. The results reported, however, have been corrected for this error in the following manner. The inspiratory volumes as recorded by the kymograph are true measurements whether the soda-lime cylinder is removed or not. As stated previously, the areas beneath the curves of the pneumotachograph tracing are directly proportional to the volume of the inspiratory and expiratory components of the tidal air. Therefore, for each tracing in which this error was present the areas beneath the pneumotachograph curves were measured with a planimeter and the true expiratory volumes found by proportion.

RESULTS OBTAINED

A group of eight patients on the surgical service of the University of Minnesota Hospitals was chosen to furnish a control series. These patients were considered to have normal lungs. They complained of no symptoms referable to the chest and gave no history of chronic pulmonary disease. On physical examination their lungs were considered to be within normal limits. The elastic factors of Neergaard and Wirz and of Christie and McIntosh as determined for each of these cases, together with other pertinent information, have been summarized and presented in Table I.

In Table II the results obtained in a second group of patients are presented. These patients were carefully selected on the basis of a long history of pulmonary disease. Since the intention was to select cases in which the elasticity of the lungs would probably be abnormal, namely, decreased, patients in whom pulmonary emphysema was thought possibly to be present were selected. In other words, the patients in this group had had bronchial asthma or chronic bronchitis for a relatively long time. There is one exception. Case 3, Mr. A. F., had no history or physical findings of any pulmonary disease. Upon a routine roentgenologic examination o fthe chest, a marked degree of emphysema was noted. For this reason alone the elasticity of his lungs was determined.

The results in a small group of miscellaneous cases have been summarized in Table III. Measurements in Cases 2 and 4 of this group were made incidental to the establishment of a pneumothorax for diagnostic purposes.

Figs. 2, 3, 4, and 5 represent portions of the graphs obtained in patients with lungs thought to be normal. These figures correspond to Cases 1, 2, 5, and 8, respectively, in Table I. Figs. 6, 7, 8, 9, and 10 are taken from graphs of patients with chronic pulmonary disease, Cases 2, 4, 5, 9, and 10, respectively, in Table II. On these graphs the maximum and minimum values of the intrapleural pressure for each respiration have been inscribed. These pressures are given in centimeters of water. In addition, the volume of the tidal air in cubic centimeters has been added at the bottom of each graph.

TABLE I

PATIENTS WITH LUNGS THOUGHT TO BE NORMAL

CASE	CLINICAL DIAGNOSIS	VITAL CAPACITY (C.C.)	AVERAGE VOLUME OF TIDAL AIR (C.C.)	AVERAGE INTRAPLEURAL PRESSURE IN CM. OF WATER		ELASTIC FACTOR OF NEERGAARD AND WIRZ	ELASTIC FACTORS OF CHRISTIE AND MC INTOSH		X-RAY DIAGNOSIS OF ROENTGENOGRAMS OF CHEST
				INSPIRATION	EXPIRATION		UNIT OF PULMONARY DISTENSIBILITY	COEFFICIENT OF PULMONARY DISTENSIBILITY	
1. Mr. O. N., U. H. No. 632170 Age: 19 yr.	Repair of inguinal hernia 6 days before	3,000	450	-7.9	-2.6	1.96	1.17	5.3	Normal
2. Mr. T. I., U. H. No. 666793 Age: 25 yr.	Appendectomy 6 days before	3,500	590	-11.9	-4.3	2.99	1.28	7.6	Normal
3. Miss M. C., U. H. No. 612129 Age: 34 yr.	Partial obstruction of the small bowel decompressed without operation 4 days before	2,400	390	-2.3	+1.4	1.45	.94	3.7	1+ Emphysema
4. Mr. J. K., U. H. No. 666254 Age: 58 yr.	Gastroenterostomy 20 days before	3,400	280	-4.1	-0.7	1.16	1.21	3.4	1+ Emphysema
5. Mr. N. K., U. H. No. 652417 Age: 68 yr.	Lipoma excised from thigh 6 days before	3,900	530	-7.1	-0.3	.96	1.28	6.8	1+ Emphysema 2+ Fibrosis
6. Mr. C. I., U. H. No. 667218 Age: 74 yr.	Repair of incarcerated inguinal hernia repaired 7 days before	3,500	690	-6.7	-0.6	2.10	.79	6.1	Normal
7. Mr. J. R., U. H. No. 666983 Age: 78 yr.	Lipoma of arm excised 5 days before	2,600	480	-7.7	-0.2	2.49	1.56	7.5	1+ Fibrosis
8. Mr. W. G., U. H. No. 667079 Age: 84 yr.	Carcinoma of lower lip	3,800	590	-3.9	+0.8	2.52	.79	4.7	1+ Emphysema

In order to furnish a basis for the evaluation of the elastic factors computed for each case, several items of information have been given.

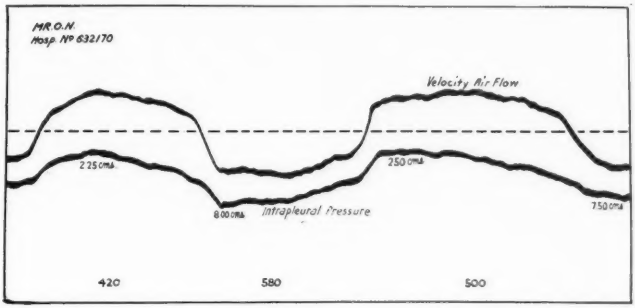

Fig. 2.—Registration of intrapleural pressure and velocity of air flow in the trachea for Mr. O. N., Case 1, Table I. Respiration was slow and without effort.

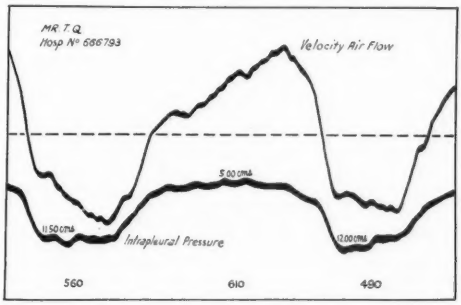

Fig. 3.—Registration of intrapleural pressure and velocity of air flow in the trachea for Mr. T. I., Case 2, Table I. This is a typical tracing for a normal person in whom the respiratory rate is somewhat increased.

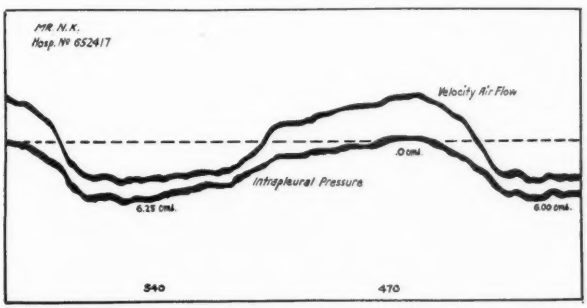

Fig. 4.—Registration of intrapleural pressure and velocity of air flow in the trachea for Mr. N. K., Case 5, Table I. This tracing resembles that in Fig. 2. The respiratory rate is slow, but the mean intrapleural pressure is somewhat higher than usual.

The patient's age, clinical diagnosis, and duration of disease were considered to be important, especially in those patients with chronic pul-

monary disease. The vital capacity represents the best effort of three attempts just before the tracings were made. None of the patients

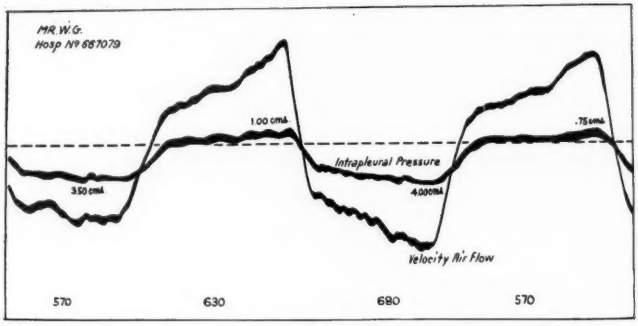

Fig. 5.—Registration of intrapleural pressure and velocity of air flow in the trachea for Mr. W. G., Case 8, Table I. This tracing resembles Fig. 3 in that the patient is breathing at a slightly increased rate. It will be noted that the mean intrapleural pressure is rather high. This is not infrequently seen in elderly persons. See Fig. 4.

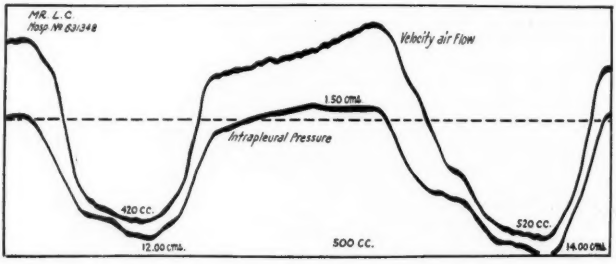

Fig. 6.—Registration of intrapleural pressure and velocity of air flow in the trachea for Mr. L. C., Case 2, Table II. This patient was dyspneic all the time because of his asthma. The prolonged expiration is quite evident from the tracing.

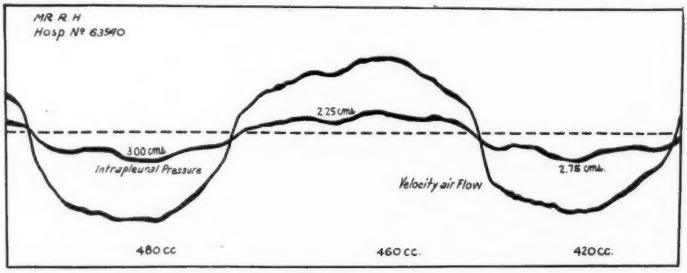

Fig. 7.—Registration of intrapleural pressure and velocity of air flow in the trachea for Mr. R. H., Case 4, Table II. This tracing resembles closely similar tracings for elderly persons with normal lungs. Despite the presence of bronchial asthma and chronic bronchitis for the past eight years, the pulmonary elasticity has not been impaired.

were trained or practiced beforehand. The volume of tidal air and other numerical values represent average values of 6 to 12 respira-

tions in each case. Before measuring the pulmonary elasticity of any patient a roentgenogram of the chest was made. Later, a competent

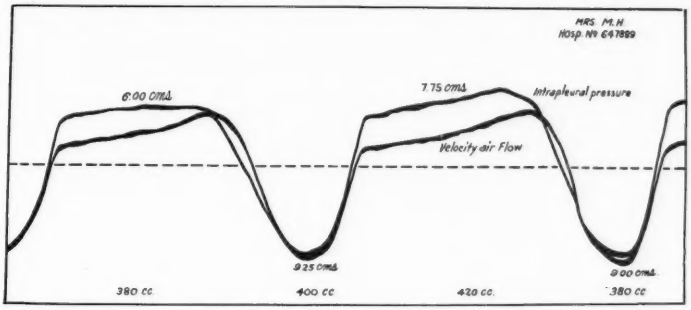

Fig. 8.—Registration of intrapleural pressure and velocity of air flow in the trachea for Mrs. M. H., Case 5, Table II. There is definite evidence of impaired pulmonary elasticity. Note the high intrapleural pressure in the prolonged expiratory phase of respiration.

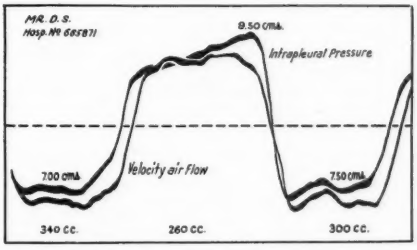

Fig. 9.—Registration of intrapleural pressure and velocity of air flow in the trachea for Mr. D. S., Case 9, Table II. By x-ray examination it is known that this patient has a marked pulmonary fibrosis. From the tracing it is evident that the pulmonary elasticity is greatly decreased.

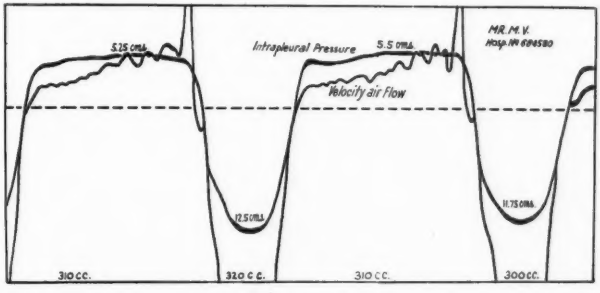

Fig. 10.—Registration of intrapleural pressure and velocity of air flow in the trachea for Mr. V. M., Case 10, Table II. This is a striking record of a patient with far advanced pulmonary emphysema who was continually gasping for breath. Note the tremendous change in the rate of air flow in the trachea with respiration.

radiologist reviewed all these films and noted those conditions which were known to affect pulmonary elasticity, namely, fibrosis and

TABLE II

PATIENTS WITH CHRONIC PULMONARY DISEASE (CHRONIC BRONCHITIS, BRONCHIAL ASTHMA, PULMONARY EMPHYSEMA)

CASE	CLINICAL DIAGNOSIS	DURATION OF DISEASE (YEARS)	VITAL CAPACITY (C.C.)	AVERAGE VOLUME OF TIDAL AIR (C.C.)	AVERAGE INTRAPLEURAL PRESSURE IN CM. OF WATER		ELASTIC FACTOR OF NEERGAARD AND WIRZ	ELASTIC FACTORS OF CHRISTIE AND MCINTOSH		X-RAY DIAGNOSIS OF ROENTGENOGRAMS OF CHEST
					INSPIRATION	EXPIRATION		UNIT OF PULMONARY DISTENSIBILITY	COEFFICIENT OF PULMONARY DISTENSIBILITY	
1. Mr. M. W., U.H. No. 662572 Age: 23 yr.	Chronic bronchitis, bronchial asthma, pulmonary emphysema	16	3,100	510	−15.2	−4.00	16.07	2.19	11.20	3+ Emphysema
2. Mr. L. C., U.H. No. 631348 Age: 29 yr.	Chronic bronchitis, bronchial asthma, pulmonary emphysema	4	2,300	490	−13.6	−1.33	3.07	2.50	12.27	2+ Emphysema
3. Mr. A. F., U.H. No. 670911 Age: 40 yr.	Carcinoma of colon	?	4,700	600	−16.24	−0.3	1.54	2.66	15.95	2+ Emphysema
4. Mr. R. H., U.H. No. 635070 Age: 33 yr.	Chronic bronchitis, bronchial asthma	5	2,850	440	−2.69	+1.88	.80	1.04	4.57	1+ Emphysema
5. Mrs. M. H., U.H. No. 647889 Age: 46 yr.	Bronchial asthma, pulmonary emphysema	28	2,100	380	−9.31	+7.75	10.54	4.49	17.06	3+ Emphysema

6. Mr. M. C., U.H. No. 650106 Age: 47 yr.	Bronchial asthma, pulmonary emphysema, carcinoma of lung	32	3,000	490	−8.37	+4.55	5.04	2.63	12.92	3+ Emphysema
7. Mrs. M. B., U.H. No. 659634 Age: 50 yr.	Bronchial asthma	20	1,900	470	−9.8	−1.75	–	1.71	8.05	Normal
8. Mr. H. D., U.H. No. 671296 Age: 65 yr.	Pulmonary emphysema, bronchial asthma	1	3,000	640	−5.3	+2.93	2.42	1.28	8.23	3+ Emphysema
9. Mr. D. S., U.H. No. 665871 Age: 65 yr.	Chronic bronchitis, bronchial asthma, pulmonary emphysema	10	3,000	360	−6.46	+8.82	8.11	4.24	15.28	1+ Emphysema 3+ Fibrosis
10. Mr. M. V., U.H. No. 664680 Age: 70 yr.	Chronic bronchitis, bronchiectasis, pulmonary emphysema	5	1,900	320	−12.06	+5.37	5.93	5.44	17.43	4+ Emphysema
11. Mr. R. N., U.H. No. 633818 Age: 77 yr.	Chronic bronchitis, bronchial asthma, pulmonary emphysema	13	3,000	250	−22.32	−0.50	2.81	8.73	21.83	4+ Emphysema

TABLE III

MISCELLANEOUS PATIENTS

CASE	CLINICAL DIAGNOSIS	DURATION OF DISEASE (YEARS)	VITAL CAPACITY (C.C.)	AVERAGE VOLUME OF TIDAL AIR (C.C.)	AVERAGE INTRAPLEURAL PRESSURE IN CM. OF WATER		ELASTIC FACTOR OF NEERGAARD AND WIRZ	ELASTIC FACTORS OF CHRISTIE AND MC INTOSH		X-RAY DIAGNOSIS OF ROENTGENOGRAMS OF CHEST
					INSPIRATION	EXPIRATION		UNIT OF PULMONARY DISTENSIBILITY	COEFFICIENT OF PULMONARY DISTENSIBILITY	
1. Mr. G. K., U. H. No. 997a Age: 50 yr.	Rheumatic heart disease	30	2,500	710	−5.08	+3.75	.54	1.24	8.83	General enlargement of heart
2. Mr. W. W., U. H. No. 665784 Age: 52 yr.	Carcinoma of lung	1	2,500	650	−2.66	+3.33	.68	.92	5.99	Area of increased density in right lung
3. Mr. M. P., U. H. No. 665661 Age: 65 yr.	Sarcoma of chest wall, pulmonary tuberculosis	1/3		740	−6.8	+10	2.06	.90	6.7	1+ Emphysema
4. Mr. M. S., U. H. No. 666785 Age: 68 yr.	Carcinoma of lung	1/4	2,500	830	−5.35	+10.21	.77	1.80	15.56	Area of increased density in left lung

emphysema. The results of this appraisal appear in the column on the right of each table.

DISCUSSION OF RESULTS

The results presented must be considered from two viewpoints. The first question to be decided is which of the patients studied have lungs of normal elasticity and which have lungs of abnormal elasticity. If this question can be answered satisfactorily, the best measure of the pulmonary elasticity can then be considered. It is admitted that the number of cases studied is small. Yet, the number of cases reported in the literature in which pulmonary elasticity has been studied is remarkably small. Neergaard and Wirz report only three and Christie and McIntosh five, in addition to a series of five other cases with pulmonary congestion due to cardiac decompensation.

It was somewhat surprising to see the number of those patients in Table I, considered to have normal lungs clinically, that, from the roentgenologic standpoint, presented minimal chest findings indicative of decreased pulmonary elasticity, that is, of emphysema and fibrosis.

The author is inclined to discount to a large extent these minimal x-ray findings. The roentgenologist has his limitations and in many borderline cases is of no help to the clinician. The functional significance of increased bronchial markings and other signs of pulmonary fibrosis are debated by radiologists. Variations in the technique of taking roentgenograms, such as the time of exposure, strength of current used, and the time in the respiratory cycle at which the film is made, even with the most careful technique may cause sufficient variation in the finished film to give the appearance of emphysema in some patients with normal lungs. These factors seem merely to emphasize the need of a more accurate method of estimating pulmonary elasticity. It may be concluded, therefore, with a fair amount of assurance that the lungs of the patients in Table I are probably within normal elastic limits and that the results obtained in computing their elasticity should fall within normal limits.

Whereas the opinion of the radiologist as to the presence or absence of minimal amounts of pulmonary emphysema or fibrosis must be accepted with a certain amount of reservation, it is said that marked degrees of these conditions can be diagnosed on the roentgenogram with certainty. Therefore, it may be concluded that, with the exception of Cases 4 and 7 in Table II, the patients with chronic pulmonary disease that were studied probably had lungs with less than normal elasticity.

The average vital capacity of those patients with lungs thought to be normal was approximately 3,240 c.c., a value somewhat lower than might be expected. It must be remembered, however, that all of these patients had been hospitalized for surgical lesions and, for the most

part, were recuperating from recent surgical procedures when these studies were made. The average vital capacity for those patients with chronic pulmonary disease was approximately 2,800 c.c. No explanation can be offered for the unusually large vital capacity (4,700 c.c.) of Case 3 in Table II. This patient had no symptoms referable to the lungs. On physical examination the chest was normal except for a moderate increase in anterior-posterior diameter characteristic of the so-called "barrel chest." The x-ray revealed increased radiability of the lung fields with wider separation of the ribs than was considered to be normal. The domes of the diaphragm were slightly flattened and depressed. If this case be excluded, the average vital capacity of the patients in Table II is 2,615 c.c.

The tidal air volumes show considerable variation between the persons of each group, as might be expected. The average values were as follows: 500 c.c. for the control group; 450 c.c. for the group with pulmonary disease; and 730 c.c. for the miscellaneous group. The mean intrapleural pressure in those patients with lungs thought to be normal is slightly greater (−7.0 cm. water) than in the patients with chronic pulmonary disease (−8.7 cm. water).

The elastic factor of Neergaard and Wirz as determined for those patients with normal lungs was found to vary between .96 and 2.99, with an average value of 1.95. These values correlate fairly well with Neergaard's own determination of 1.54 in a normal person and 0.9 in a patient with pulmonary tuberculosis of the right upper lobe. In the group of patients with chronic pulmonary disease, Neergaard and Wirz's elastic factor varies over such a wide range, however, that doubt of its value is immediately raised. Furthermore, none of the values found in this group approach the value 0.6 which Neergaard and Wirz have reported in a patient with moderate pulmonary emphysema. Certain other facts throw additional doubt upon the clinical value of Neergaard and Wirz's method. If the elastic factor be determined on successive respirations occurring on the same tracing, this factor will be found to vary frequently by several hundreds per cent from one breath to another, and all too frequently the computed factor is found to be zero. These considerations have led the author to conclude that, as determined in this study, the elastic factor of Neergaard and Wirz is unsuitable for clinical use. For this reason no attempt has been made to determine the modulus of elasticity by this method.

In fairness to Neergaard and Wirz it must be made clear, however, that, whereas they have advocated a special trochar of 3 mm. lumen, we have used a No. 17 needle. It is possible, of course, that the increased resistance which is thus made to the passage of air and, hence, the transmission of intrapleural pressure vitiate the method. We have used the trochar recommended by Neergaard and Wirz many times while

measuring the intrapleural pressure of dogs but, being impressed with the force required to pass it through the thoracic wall, have hesitated to employ it on patients in whom only a small area of the chest was anesthetized with novocaine. The same variation in the elastic factor was found when the trochar was used in determining the elasticity of the lungs of dogs as has been mentioned as occurring in the clinical cases in which the trochar was not used.

The elastic factors of Christie and McIntosh are apparently much more valuable to the clinician. The results obtained from the patients studied in this series fully confirm Christie's contention that, while the unit and coefficient of pulmonary distensibility vary considerably among individual patients, they are remarkably constant in the same person. In the control series of eight patients the unit of pulmonary distensibility was found to vary between 0.79 and 1.56, with an average of 1.13. This compares favorably with Christie's reported average value of 1.29 as determined for five patients with minimal pulmonary tuberculosis. The coefficient of pulmonary distensibility for this same control group varied from 3.4 to 7.6, with an average value of 5.6.

The unit, as well as the coefficient, of pulmonary distensibility is increased in those patients with lungs of decreased elasticity. This is more noticeable in the values determined for the coefficient of distensibility. Eight patients with marked emphysema were found to have a coefficient of distensibility varying from 11.20 to 21.83. In one other patient with slight emphysema but marked pulmonary fibrosis, the coefficient of distensibility was 15.28. Case 8, Mr. H. D., University Hospital No. 671296, is apparently an exception. Although, as determined by x-ray examination of the chest, this patient had a marked degree of pulmonary emphysema, the unit of pulmonary distensibility is well within the range as determined for patients with normal lungs. Some decrease in pulmonary elasticity, however, is indicated by a coefficient of distensibility of 8.23, although this is considerably lower than the same value found in clinically similar patients.

These considerations have led us to the conclusion that the estimation of the coefficient of distensibility is the best clinical measurement of pulmonary elasticity. It is relatively easy to estimate, requiring only the measurement of the intrapleural pressure change occurring during the course of a regular inspiration. This method, though simpler than that of Neergaard and Wirz, is not without its disadvantages. In six of the twenty-three cases reported, pneumothorax of considerable proportion occurred following the insertion of the needle into the pleural space to measure the intrapleural pressure. Five of these instances occurred in those patients with chronic pulmonary disease. None of these pneumothoraces produced serious consequences except a considerable embarrassment upon the part of the

author and moderately increased dyspnea and discomfort on the part of the patient. Yet, the potentialities for serious consequences exist under these circumstances and must be borne in mind. These instances are mentioned only to emphasize the fact that the insertion of a needle into the intrapleural space is not to be considered a matter of trivial importance.

Since the number of patients in the miscellaneous group is so small, these cases have not been considered in the discussion of the results. The results obtained in this small group have been presented for the sake of completeness.

SUMMARY

The elasticity of the lungs of twenty-three patients has been computed according to the methods of Neergaard and Wirz and of Christie and McIntosh from data obtained by registering simultaneously the intrapleural pressure, the velocity of air flow in the trachea, and the volume of the tidal air. A description of each method has been given. Patients with lungs thought to be normal, patients with chronic pulmonary disease in which the pulmonary elasticity was thought to be probably decreased, and certain patients with miscellaneous pulmonary pathologies have been studied. Portions of the tracings obtained in representative cases have been reproduced. A tabulation of the average values necessary for the computation of the pulmonary elasticity for each case has been made. These results have been discussed, and clinical value of the two methods for the estimation of elasticity has been considered.

CONCLUSIONS

1. The method of Christie and McIntosh for measuring the elasticity of the lungs in the living patient is superior to the method of Neergaard and Wirz. The technique required is simpler and the results more consistent.

2. In eight patients with lungs thought to be normal, the change in intrapleural pressure accompanying an increase in the volume of the lungs of 100 c.c. (unit of pulmonary distensibility) was found to vary from 0.79 to 1.56. The change in intrapleural pressure accompanying an ordinary inspiration (coefficient of pulmonary distensibility) in this same group of patients was found to vary from 3.4 to 7.6. This latter factor is the best measure of pulmonary elasticity.

3. In ten patients with bronchial asthma, chronic bronchitis, or both, the pulmonary elasticity was found to be decreased in nine and markedly decreased in seven.

4. The roentgenologic diagnosis of minimal amounts of pulmonary emphysema is doubtful. In the presence of marked emphysema the radiologic interpretation of the chest film correlates well with the measurement of pulmonary elasticity.

5. In eight cases with moderate to severe pulmonary emphysema as determined by x-ray examination of the chest, the unit of pulmonary distensibility was found to vary from 2.19 to 8.73 and the coefficient of pulmonary distensibility from 11.20 to 21.83.

6. In six of the twenty-three cases studied, pneumothoraces of considerable proportions occurred following the insertion of a needle into the intrapleural space. Five of these patients had chronic pulmonary disease.

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THORACIC LIPOMAS

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ALTHOUGH reports of thoracic lipomas have appeared in the medical literature from time to time since the first case reported by Fothergill in 1783, there have been, to date, only thirty-four cases recorded, including the one reported herein. The most comprehensive report of these tumors is given by Heuer,[1] who divided the cases into three groups according to their anatomic location. These divisions are (1) those lipomas in which an intrathoracic tumor is continuous with an extrathoracic tumor, giving rise to a growth with an hourglass form; (2) those in which a mediastinal tumor extends into the neck; and (3) those which lie entirely within the thoracic cage.

In reviewing these cases it will be seen that the symptomatology runs the gamut from no symptoms to the signs and symptoms of distressing intrathoracic compression.

In this communication our case, which belongs to the third group, will be presented along with an attempt to tabulate the signs and symptoms most commonly found in each group of the thoracic lipomas.

CASE REPORT

History.—A 32-year-old Mexican female was first seen in the Tuberculosis Clinic of the Robert B. Green Memorial Hospital in 1936, complaining of dyspnea on walking and a nonproductive cough. Her condition was diagnosed as asthma, and injections of adrenalin gave her relief.

About a year later she appeared at the Clinic with extreme dyspnea and hemoptysis. Adrenalin again gave her relief.

In December, 1937, she again had a paroxysm of shortness of breath which was diagnosed as asthma. However, at this time she had an elevation of temperature which had not been present previously.

In April, 1938, the patient again presented herself at the Tuberculosis Clinic with the complaints of productive cough, loss of weight, night sweats, dyspnea, ease of fatigue, afternoon elevation of temperature, poor appetite, pain in the chest, and hemoptysis. Questioning at this time revealed a sister who had pulmonary tuberculosis. Physical examination showed fine and medium râles over the upper half of the left chest and flatness to percussion over the entire left thorax.

X-ray examination (Figs. 1a and 1b) showed an extensive shadow in the left side of chest, with displacement of the heart and mediastinal contents to the right. The diagnosis of pleurisy with effusion was made. Repeated attempted aspirations failed to reveal fluid. Intrathoracic tumor was then considered, and deep x-ray therapy was administered, with relief of dyspnea and orthopnea. This treatment gave relief for about two months, but on Oct. 15, 1938, she returned

From the Woodmen of the World Memorial Hospital, San Antonio.
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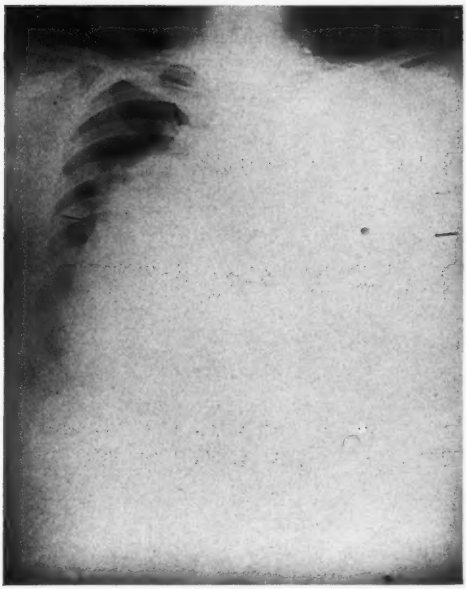

Fig. 1a.—X-ray of the chest shows a dense shadow occupying the entire left chest, with displacement of the mediastinum to the right nipple line.

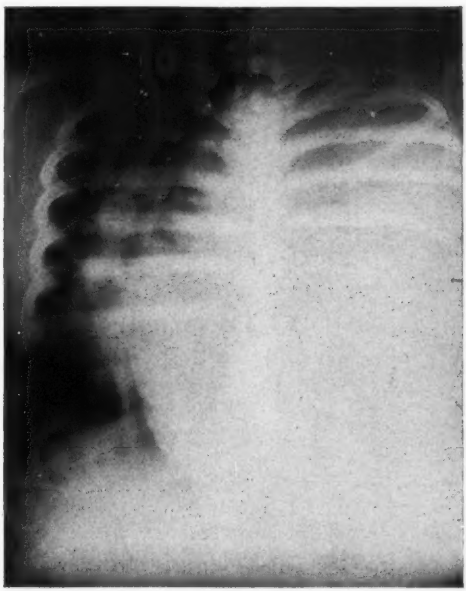

Fig. 1b.—This x-ray, which is more heavily exposed than the one shown in Fig. 1a, shows the opacity in the chest to be less dense toward the periphery. This illustrates the contention of Heuer that the shadow cast by lipomas is less dense at the edges, a characteristic not observed in x-rays of collections of fluid.

with the symptoms of dyspnea, orthopnea, and swelling of the feet. The patient was admitted to the Robert B. Green Memorial Hospital for exploratory thoracotomy.

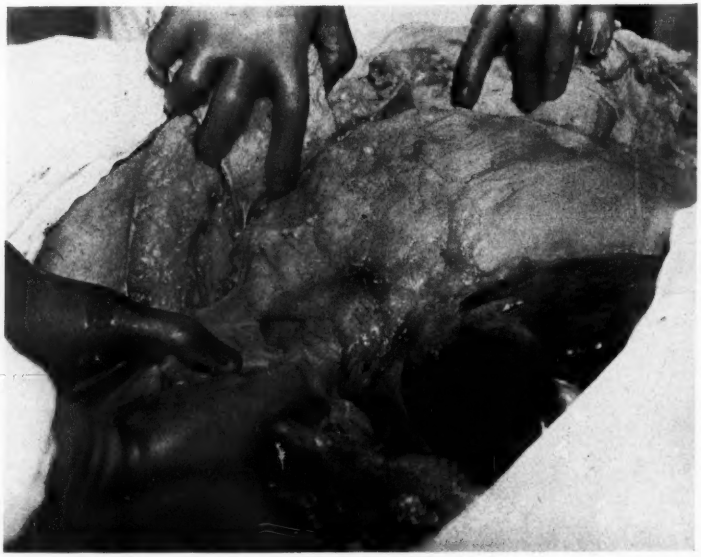

Fig. 2.—View of lipoma in situ, causing complete atelectasis of left lung with displacement of mediastinal contents to the right.

Fig. 3.—The tumor mass as it appeared when partially removed from the chest. This lipoma weighed 16 pounds.

Physical Examination.—Examination showed edema of the face and feet, cyanosis of the lips, and dullness in the left chest with displacement of the heart to the

right. The point of maximal impulse was located in the right midclavicular line, and respiration was labored and rapid. The erythrocyte count was 3,460,000, and the leucocyte count was 17,060, with 62 per cent polymorphonuclear cells. Other

Fig. 4.—Anterior view of the lipoma, with the heart and right lung attached.

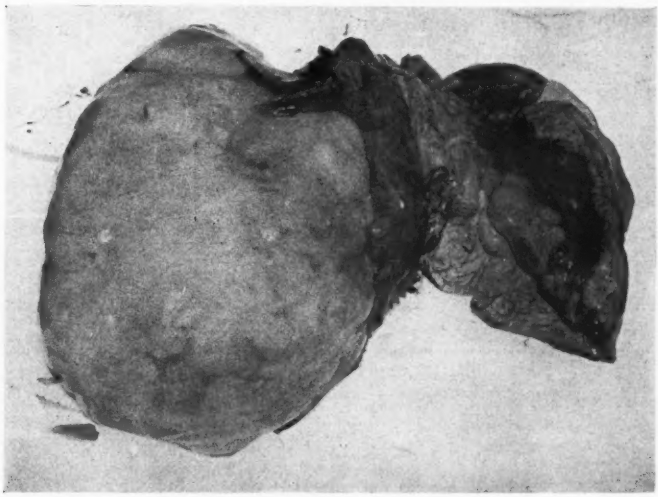

Fig. 5.—Posterior view of the lipoma, showing the atelectatic left lung and the congested right lung.

laboratory examinations were negative. The patient was given oxygen insufflation, with immediate but temporary relief. Her condition became progressively worse after admission, and she died on Oct. 16, 1938, apparently from suffocation.

Post-Mortem Report.—Autopsy showed a large mass occupying the entire left chest, extending from apex to diaphragm, with marked displacement of the heart, trachea, and mediastinal contents to the right. The right margin of the heart was just past the right nipple line. The right lung was partially atelectatic, while the left lung was completely collapsed. The large growth (Figs. 2-5) was smooth and encapsulated and was attached anteriorly to the root of the left lung and mediastinal structures at the level of the first part of the aorta. Except for a few adhesions on the surface, the mass lay free in the pleural space. The neoplasm was faintly nodular on palpation, and it consisted of yellow fatty tissue, being grayer and firmer in areas. Toward the base of the mass in the midaxillary line was a large fibrous plaque, probably the site of penetration at attempted aspiration. The tumor appeared grossly to be a lipoma.

All abdominal viscera were passively congested, and the spleen was enlarged. When removed, the tumor weighed 16 pounds and measured 30 by 21 by 15 cm.

Microscopic Description.—The tumor was composed of essentially normal-appearing fatty tissue, with marked variation in the size of lobules. Some of the cells were widely distended with fat, with the nucleus compressed in signet form against one side. Other cells were small and contained only a small amount of fat. There were a number of fairly large polyhedral cells present in which lipoid deposits were scanty. The cells appeared loose and foamy. The tumor was fairly vascular, and in some of the trabeculae there were accumulations of lymphocytes around some of the vessels. No malignant degeneration was found.

Pathologic diagnosis was benign lipoma of the left pleural cavity, probably originating in the mediastinum.

Table I shows the most common signs and symptoms and the number of cases in which each was found. Because of the lack of data concerning the symptoms of some of the cases, this tabulation, of necessity, is not entirely representative.

The diagnosis of the intrathoracic type of lipoma was most often mistaken in this series for a collection of fluid. In this connection it may be said that the sensation produced by passing a needle into a lipoma is different from that produced by a collection of fluid. In the former case

TABLE I

MOST COMMON SIGNS AND SYMPTOMS PRESENT IN THE CASES OF THORACIC LIPOMA REPORTED IN THE LITERATURE FROM 1783 TO 1939

SIGNS AND SYMPTOMS	NUMBER OF CASES
Pain	11
Dyspnea	16
Palpable tumor	14
Cough	7
Shadow shown in chest by x-ray	9
Hoarseness	2
Cyanosis	8
No symptoms (tumor found on autopsy)	5
Edema of lower extremities	3
Hemoptysis	2
Elevation of diaphragm on affected side	1
"Symptoms of angina pectoris"	1
"Cardiac symptoms"	1
"Disturbance of cardiac rhythm"	1

the sensation is that of penetrating a buttery or boggy mass, while a pleural fluid collection has more of a tense elastic resistance.

A further aid to diagnosis is given by Heuer[1] who concluded from his case that the x-ray shadow cast by a lipoma is characteristic. The edges of the shadow cast by a lipoma suggest transparency when compared with the dense central portion, while the shadow cast by a massive collection of fluid shows no tendency to be transparent near the edges.

The following case summaries and their classifications are taken from a review of literature on lipomas by Heuer (1933), with the addition of case histories reported since 1933.*

These summaries are presented in order to allow one to observe more easily the most outstanding features of the reported cases.

GROUP 1: HOURGLASS TUMORS

CASE 1 (Cruveilhier, J.: Traite d'Anatomie pathol. generalis, Paris, 1856, Baillière, vol. 3, p. 315).—A patient presented a fatty tumor over the sternum which at operation presented several prolongations at the lateral border of the sternum, penetrating the thoracic wall and connecting with an anterior mediastinal tumor. The extrathoracic portion of the tumor was removed at operation and the connecting portions were partially delivered by traction, but the mediastinal tumor was not removed. The patient died of a suppurative process developing in the anterior mediastinum following operation.

CASE 2 (Czerny, J. G.: Wien. med. Wchnschr. 25: 166, 1875).—The patient was an 18-year-old male who complained of a tumor on his back, pain in the left axilla, and dyspnea. He had been well until three years previously when his back was injured. Following the injury a tumor appeared on his back and grew rapidly. Physical examination showed a well-developed man, with a tumor the size of a "man's hand" below the left scapula.

The overlying skin was not adherent, and, upon attempted aspiration of the smooth tumor, no fluid was obtained. The preoperative diagnosis of lipoma was made. At operation, the external tumor was found to be continuous with a pedicle perforating the seventh intercostal space. The pedicle was the size of a "hen's egg" in circumference, and the intrathoracic portion, which was removed piecemeal, was the size of a "fist." The patient died on the fourth postoperative day of infection. Autopsy showed a purulent pleurisy and an edematous and bloody lung.

CASE 3 (Vogt, Carl: Dissertation, Berlin, 1876. This case is also known as Kronlein's or Langenbeck's).—An infant 1 year old was brought to the clinic because of a painless tumor over the right anterior thorax. The tumor had been noticed six months previously and had grown rapidly. The external tumor extended from the lower margin of the clavicle to the xiphoid and laterally from a point two fingerbreadths to the left of the sternum to the right axilla. The skin over the tumor was freely movable; the tumor was soft and lobulated. Dullness was found on percussion of the thorax about the mass, and faint breath sounds were present in the same area. At operation, the tumor was perceived to narrow into a pedicle which pierced the third interspace 1 cm. to the right of the sternum. The external tumor was removed. The gross and microscopic diagnosis of the tissue removed was lipoma.

*Cases marked thus were not included in the review of literature by Heuer.

Five days after operation the patient's temperature rose to 104° F., dyspnea appeared, and he died on the eighth postoperative day due to a condition diagnosed as erysipelas.

Autopsy revealed a mediastinal lipoma extending from manubrium to xiphoid and displacing the heart posteriorly and to the left. The lipoma when enucleated measured 11 by 10 by 8.5 cm. Purulent pleurisy and pneumonia were present.

CASE 4 (Plettner, G. A. L.: Inaug. Diss., Halle, 1889).—An elderly white woman presented a mass over the left thoracic wall. (Further details concerning the patient were lacking.) On operation the tumor was revealed to narrow and pass through the chest wall in the axilla between the fourth and fifth ribs. The extrathoracic portion of the growth was removed and diagnosed as lipoma. The patient died of an inflammation involving the severed pedicle.

At autopsy a "subpleural" lipoma was found, continuous with the remaining portion of the pedicle. A septic pleurisy and pericarditis were also found.

CASE 5 (Gussenbauer, Carl: Arch. f. klin. Chir. **43**: 322, 1892).—This patient was a 42-year-old woman who complained of cough and swelling under the left breast. Examination showed a mass under the upper part of left breast extending into the left axilla. The tumor was larger than a "man's fist" and was soft and elastic to palpation. Percussion of the chest about the tumor revealed dullness which merged with the cardiac dullness. At operation the tumor was found to be covered with a delicate capsule which also encased a prolongation of the growth piercing the second intercostal space. The intrathoracic portion of the tumor was freed and removed after resection of the third costal cartilage. The wound was drained, and after a stormy period of three weeks, the patient recovered. The neoplasm weighed 500 Gm. and apparently was covered by endothoracic fascia.

CASE 6 (Garnier, C., and Grosjean, L.: Rev. méd. de l'est **35**: 654, 1903).—This patient was a white male, aged 56 years, who complained of pain in and about the sternum which had been present for three months. The pain called the patient's attention to a swelling sensitive to pressure located over the sternum.

There were no other symptoms referable to the tumor. Upon examination, the mass was the size of an "egg" and located over the xiphoid process in the midline. It was soft, slightly fluctuant, and painful upon palpation, and the skin over it was freely movable. Aspiration was attempted, but no fluid was obtained. At operation a tumor was found to extend through the sternum by means of a pedicle. The mediastinal portion of the tumor was delivered through the opening in the sternum. The neoplasm was diagnosed as lipoma. The patient made an uneventful recovery.

CASE 7 (Harms, Claus: Ztschr. f. Chir. **47**: 668, 1920).—The patient presented a swelling over the right side of the chest which had been present for two years and which was painful and rapidly increasing in size. There were no other symptoms. On examination the tumor was found to be the size of a "small apple" and located to the right of the sternum at the level of the second rib. It was soft and fluctuant and immovably fixed to the thoracic wall. X-ray examination did not show any intrathoracic shadow. Attempted aspirations resulted in no fluid being obtained. The mass was diagnosed as lipoma or sarcoma. At operation a lipoma was found under the pectoralis major, with a pedicle the size of one's "thumb" extending into the mediastinum and through the second interspace. The mediastinal portion of the tumor was small and was readily removed. It was called a subpleural lipoma. The patient made an uninterrupted recovery.

CASE 8 (Beyers, C. F.: Lancet 1: 283, 1923).—The patient, a 22-month-old male, was brought under observation because of a swelling over the anterior thoracic wall which had been present a year and which was rapidly increasing in size. Physical examination showed a pale, but healthy, child, who presented a lobulated, fluctuant tumor 2 inches in diameter to the left of the sternum over the fifth, sixth, and seventh costal cartilages. The diagnosis was cold abscess from a tuberculous rib. At operation a lipoma was exposed, presenting a pedicle which penetrated the thoracic wall in the sixth interspace. The sixth and seventh costal cartilages were resected, and the mediastinal tumor was removed. The lipoma presented a dumbbell appearance upon removal. The patient made an uneventful recovery.

CASE 9 (Walzel, P.: Arch. f. klin. Chir. 170: 112, 1932).—A male 15 months of age came under observation because of a mass in the right axilla. It was first noticed six months previously and had been growing rapidly since. The tumor was at first without symptoms, but later dyspnea and cyanosis had developed. The axillary swelling was the size of a "mandarin"; the skin was freely movable above the tumor, but the tumor itself was firmly fixed to the thoracic wall. X-ray of the thorax showed a shadow in the right chest and a widening of the right third and fourth interspaces. Aspiration of the tumor revealed no fluid. From a biopsy of the external portion, a diagnosis of lipoma was made. At operation the external neoplasm was found to be connected to a pedicle which penetrated the third interspace. The outer portion of the tumor was removed, and portions of the third to the fifth ribs were removed. The intrathoracic mass was adherent to the pleura, and in its removal, the pleura was torn. The entire lipoma was removed, and the patient made an uneventful recovery. The tumor was hourglass in shape. The external portion weighed 160 Gm., and the internal, 240 Gm. The pedicle was the size of a "thumb."

GROUP 2: ANTERIOR SUPERIOR MEDIASTINAL TUMORS PRESENTING AT THE ROOT OF THE NECK

CASE 1 (Beatson, G. T.: Glasgow M. J. 51: 57, 1899).—The patient, a 45-year-old male, came under observation because of a tumor of the neck above the manubrium sterni. It had been present five years and had increased steadily in size. No record of symptoms nor of the physical examination was given. The tumor was diagnosed as a cyst of the mediastinum. At operation a lipoma the size of an "orange" was found to extend downward into the mediastinum. The mass was freed and delivered, and the patient recovered without interruption. The pathologic diagnosis was lipoma, although Mr. H. E. Clark thought it might contain some elements of the thymus.

CASE 2 (Lemon, W. S.: M. Clin. North America 8: 1247, 1925).—This patient, a 45-year-old male, came under observation at the Mayo Clinic, complaining of dyspnea, swelling of the neck, and paroxysms of coughing. These symptoms had been present for five years, and a diagnosis had been made of enlarged thyroid with pressure symptoms. Examination showed a supraclavicular mass 5 cm. in diameter; no bulging of the thoracic wall nor signs of mediastinal pressure were evident. Mediastinal dullness extended into the right chest, and there were also decreased respiratory excursion of the right chest and distant breath sounds over the same area. X-ray examination showed a large, lobulated mediastinal tumor extending into the right chest; bronchoscopic examination was negative. Biopsy of the supraclavicular portion of the tumor showed a simple lipoma. The patient

was given radiotherapy, but his symptoms continued to increase and he developed marked dyspnea, cyanosis, and paroxysms of coughing. Two years later he died, and upon post-mortem examination a mediastinal lipoma larger than a "quart cup," adherent to the trachea, aorta, and right bronchus, was found extending well into the right thoracic cavity.

CASE 3 (Graham, E. A., and Wiese, E. R.: Arch. Surg. **16**: 380, 1928).—The patient, a 43-year-old man, complained of swelling of the neck, pain in the neck and chest, choking spells, and dyspnea. The swelling in the neck which had been present for six months was increasing in size. Physical examination revealed diffuse swelling above the sternum more to the right than to the left side of the sternum, which apparently extended downward into the mediastinum. The mass was immovable, and no tenderness was present.

No substernal dullness was present. Hoarseness and cyanosis of the finger tips were present. An x-ray of the chest showed no abnormality except a high right diaphragm suggestive of a partial paralysis. Laryngoscopic examination showed the left vocal cord to be more active than the right. Through a "collar" incision a tumor measuring 9 by 5 cm. and extending 4 cm. into the anterior mediastinum was removed, with the prompt disappearance of symptoms. The tumor was a lipoma.

CASE 4 (Fitzwilliams, Duncan C. L.: Proc. Roy. Soc. Med., vol. 7, Sect. Stud. Dis. Child., p. 19, London, 1913-1914).—The patient, a child of 6 years, complained of a tumor in the neck. Physical examination revealed a tumor in the neck extending into the chest. This mass was diagnosed as a hernia of the lung and a truss was applied, but eight months later the tumor had increased to such an extent that an operation was decided upon. The whole mass was removed and proved to be a lipoma upon examination. The portion in the neck was connected by a narrow isthmus to a much larger portion within the thorax, but outside the parietal pleura. The tumor was 4¾ inches long and 4 inches wide.

CASE 5* (Abbott and Webb[2]).—The patient was a 29-year-old male who complained of a mass in the lower right anterior triangle of the neck of six months' duration, nervousness for two years, and a loss of 9 pounds in weight. The mass in the neck had gradually increased in size until, at the time of examination, it was the size of an "egg." There was no history of palpitation, increased appetite, nor heat intolerance. Neither was there dysphagia, cough, nor hoarseness present. Except for the mass in the neck, physical examination revealed no abnormalities. The tumor was soft and smooth; it was not adherent to the skin and did not move on deglutition, and its lower margin extended below the clavicle. X-ray examination of the chest showed no abnormality. At operation a tumor the size of a "lemon," lying anterior to the thyroid and extending into the superior mediastinum, was removed. The tumor was a lipoma. The patient made an uneventful recovery.

GROUP 3: THE INTRATHORACIC LIPOMAS

CASE 1 (Fothergill, John: Collected Works, London, 1783, J. Walker, p. 509. Cited by Hare and Hobart: Pathology, Clinical History and Diagnosis of Affections of the Mediastinum, London, 1883).—The details of this case are scanty. The patient, a man with symptoms of angina pectoris, died without a diagnosis of intrathoracic tumor being made. At autopsy a lipoma of the mediastinum was found which was adherent to or which involved the pericardium.

CASE 2 (Jurine, Louis: Traite de l'angine de poitrine, Appendix, Case IV, Paris, 1815, J. J. Pachoud).—A white male, 50 years of age, with the complaints of faintness and dyspnea, died and at autopsy presented a lipoma filling the entire anterior mediastinum. Microscopic examination confirmed the gross diagnosis of lipoma.

CASE 3 (Schreiber, A.: Deutsch. Arch. f. klin. Med. **27**: 52, 1880).—The patient, a white male 38 years old, had had fever, dyspnea, and cyanosis of the face for one month. He died and at autopsy presented a lipoma of the mediastinum, bloody fluid in the pericardium, and a hemorrhagic exudate in the pleural cavity. The size of the tumor was not given. Pericarditis is given as the cause of death. The case is reported by Hane in his monograph.

CASE 4 (Clark, F. W.: Path. Soc. London **38**: 324, 1887).—The patient, a white woman 65 years of age, died following an intracapsular fracture of the neck of the femur. At autopsy a rounded lobulated tumor the size of a "goose egg" was found projecting into the right pleural cavity. The base of the neoplasm spread out between the muscle fibers of the diaphragm. The author explains the situation of the tumor thus: "With reference to this specimen I would venture to state that there is normally an outgrowth of fat from the diaphragm, anteriorly close to the reflection of the pericardial pleura on to the diaphragm. This may, in cases of general obesity, become occasionally so increased in amount as almost to assume the appearance of a fatty tumor, but does not, of course, constitute a true tumor since it is but part of a general physiological process."

CASE 5 (Chiari, O.: Cited by Gussenbauer, Arch. f. klin. Chir. **43**: 322, 1892).—A woman of 62 years died of Bright's disease and endocarditis, and at necropsy an intrathoracic tumor was found. The lipoma was located beneath the pleura, lying near the left seventh rib and projecting into the thoracic cavity. The "walnut"-sized lipoma lay between the costal pleura and the endothoracic fascia.

CASE 6 (Conner, L.: Proc. New York Path. Soc. 43, 1897).—A female died of cerebral hemorrhage, and at post-mortem examination an intrathoracic lipoma was found. It was situated to the left and posterior to the cardiac apex, measured 4 by 3 cm., and was covered by the diaphragmatic pleura. The author suggested that it had its origin from the diaphragm and extended into the pleural cavity.

CASE 7 (Fitz, Reginald: Am. J. Med. Sc. **130**: 785, 1905).—A male, 34 years of age, came under observation, complaining of pain in the chest, cough with rusty sputum, and dyspnea. He had been acutely ill for two weeks and had had a chill ten days before admission. The temperature was 104° F., pulse 145, and respiration 50, and the leucocyte count was 41,200. Physical examination revealed dullness over the lower right axilla, with absence of respiratory and vocal sounds. A diagnosis of lobar pneumonia was made. The patient later developed the signs and symptoms of pericarditis, and the pericardial sac was aspirated without obtaining fluid. The patient died on the twenty-first day of his illness, and at necropsy the pericardial cavity contained 500 c.c. of opaque yellowish fluid. On the left side of the pericardium a large mass of fat divided into lobules was found attached. It was attached to the pericardium, diaphragm, pleura, and inferior lobe of the left lung. The lobe of the lung was only one-third of its normal size, dark red in color, and apparently hypoplastic. The diagnosis was intrapleural lipoma. Because of the hypoplastic state of the inferior lobe of the left lung, the author concluded the tumor to be of congenital origin.

CASE 8 (Bertoli, P.: Gazz. d. osp. **29**: 1108, 1908).—A 59-year-old man died of empyema of the right thorax. At autopsy a large lobulated lipoma was found in the mediastinum which had given no evidence of its existence during the patient's life.

CASE 9 (Garre, C.: Deutsch. med. Wehnschr. **44**: 617, 1918).—A white woman 28 years old complained of pain in the chest, difficult breathing and swallowing, and hoarseness. A previous diagnosis of pulmonary tuberculosis had been made, and she had taken a "cure" at a hospital. Physical examination revealed dullness over the right apex, and an x-ray showed an intense shadow filling the right apical region, extending downward to the sixth rib posteriorly. Intrathoracic tumor was diagnosed. The entire tumor was removed at operation through a posterior approach. It lay within the mediastinum and was adherent to the pleura. On removal the mass measured 8 by 10 cm. and weighed 270 Gm. Pathologic diagnosis was fibrolipoma. The patient recovered.

CASE 10 (Auvray, M.: Cited by Garre, Deutsch. med. Wehnschr. **44**: 617, 1918).—Garre does not give any details of this case. The author states that Auvray had a case of lipoma of the mediastinum.

CASE 11 (Leopold, R. S.: Arch. Int. Med. **26**: 274, 1920).—A white man, 37½ years old, complained of persistent cough, pain in the chest, dyspnea, and substernal oppression. The symptoms were of twenty years' duration, beginning with cough and followed by thoracic pain and dyspnea. Eventually he was unable to breathe in the recumbent position and suffered continuously from dyspnea. Physical examination showed a man who had lost a great deal of weight and who had continuous air hunger, cyanosis of the head, face, and arms, and edema of the abdomen, genitals, and lower extremities. Anteroposterior x-ray of the thorax showed a dense shadow extending from the third rib to the diaphragm and filling the entire thorax except for a small area of the lower right side. The lateral x-ray showed a similar enormous mass filling the thorax. The patient died with symptoms of mediastinal compression. Autopsy revealed a large lipoma of the anterior mediastinum measuring 31 by 30 by 15 cm. and weighing 17½ pounds. It was attached just below the sternal notch, and the heart, great vessels, and lungs were compressed against the vertebral column and displaced downward. The heart was small and atrophic. The abdomen was filled with exudate, and the viscera were congested. The lower extremities were edematous.

CASE 12 (Sauerbruch, F.: Chirurgie d. Brustorgane, Berlin, 1925, Julius Springer, vol. 11, p. 376).—A patient complained of "cardiac symptoms," and, on physical examination, he was found to have a tumor of the anterior mediastinum. The third costal cartilage was resected at operation, and the tumor was enucleated without opening the pleura. Pathologic diagnosis was mediastinal lipoma. The patient recovered.

CASE 13 (Yates, Wallace M., and Lyddane, E. Stewart: Am. J. Med. Sc. **180**: 79, 1930).—The patient, a carpenter 44 years of age, had suffered from dyspnea on exertion since an attack of influenza in 1918. Two days before he consulted the authors he became acutely ill with pain in his lower left chest, cough, and expectoration of mucoid, bloodstreaked sputum. In addition to the above symptoms, he was dyspneic on admission. The temperature was 102° F., pulse 120, respiration 28, and the leucocyte count was 13,750. Upon physical examination there was flatness to percussion over the right lower thorax, with diminished breath sounds and

crackling inspiratory râles throughout the lungs. X-ray examination of the chest showed a dense opacity of the lower two-thirds of the right chest and an opacity of the lower portion of the upper lobe. Sputum examination revealed the presence of pneumococcus, Type IV. Pneumonia was diagnosed. The patient died on the fourth day after admission, and at autopsy the right lung was found to be completely consolidated and about one-third the normal size. The heart appeared to be normal. Occupying the anterior mediastinum and largely filling the right side of the thorax was a large, yellowish tumor, 28 cm. long and weighing 8½ pounds, which, on gross and microscopic examination, was found to be a lipoma.

CASE 14 (Ewing, James: Neoplastic Diseases, Philadelphia, 1931, W. B. Saunders Co., p. 199).—The patient, a middle-aged white man, presented at autopsy a mediastinal lipoma encircling nearly all the structures of the thorax and made up of five main lobules each the size of a "goose egg." The tumor arose in the anterior mediastinum and filled one-half of the left pleural cavity.

CASE 15 (Klemperer and Rabin: Arch. Path. **11**: 385, 1931 [fourth case]).—A 41-year-old white male was admitted to the Mount Sinai Hospital on Sept. 6, 1919, complaining of pain in the right side of the chest. He was dyspneic and upon physical examination presented the signs of fluid in the right side of the chest. X-ray examination of the chest revealed a large shadow almost completely filling the right side of the thorax, which was interpreted as due to a neoplasm. The patient left the hospital, to return after a lapse of eleven years (1930). His symptoms had increased, and on his second admission he was extremely cyanotic and dyspneic and showed an enlargement of the liver and edema of the lower extremities. He died of heart failure. At autopsy there was noted marked cyanosis of the head and neck and slight clubbing of the fingers and toes. The right side of the thorax was filled with a soft tumor, larger than a man's head, which was adherent to the parietal pleura of the anterior and lateral walls of the chest. In shape it was like a cast of the right pleural cavity. It apparently had its origin in front of the right lower lobe; its base rested upon the diaphragm; and the upper pole crowded the middle and upper lobes into the dome of the pleura. The pericardial sac did not contain fluid. The heart weighed 480 Gm. Microscopic examination of the tumor showed the typical structure of a lipoma.

CASE 16 (Ruetz, A.: Zentralb. f. Chir. **59**: 41, 2477, 1932).—The patient, a young man, had a tumor of the posterior mediastinum causing displacement of the heart and disturbance of the cardiac rhythm. The tumor was removed through a posterior approach and proved to be a lipoma the size of the "fists." The patient recovered.

CASE 17 (Narr, Frederick, and Wells, Arthur: Am. J. Cancer **18**: 912, 1933).—The case was that of a 33-year-old man who had fallen and injured the lower left ribs. Subsequently, he developed the symptoms of an intrathoracic tumor. Dyspnea became so marked that operation seemed advisable. At operation the intrathoracic tumor was exposed, and as much of it as possible was removed. Postoperative x-ray therapy failed to retard the further growth of the tumor, and the patient died five years after the initial injury with a tumor which filled the entire left pleural cavity. At autopsy a large intrathoracic mass was found filling the entire left thorax and approximately the anterior half of the right thorax, forcing the diaphragm down, and filling the upper left quadrant of the abdomen. It was completely encapsulated by a thick fibrous capsule over its entire surface, except about the mediastinum. It was adherent to the diaphragm.

In places the capsule was torn through, and soft, light brown mucoid matter flowed from within. The tumor showed three types of tissue—a thick fibroid capsule, adipose tissue, and myxomatous tissue.

CASE 18 (Heuer, George J.: Ann. Surg. **98**: 801, 1933).—The patient, a young woman 24 years of age, complained of pain in the chest, shortness of breath, choking sensations, and palpitation of the heart. There had been no symptoms referable to the chest before the present illness. Eleven months before entrance to the hospital there occurred a stabbing pain in the left chest and back, intensified with each respiratory effort. She developed marked dyspnea and, when taken to another hospital, arrived in poor condition and was ashen in color and prostrated. X-ray examination of the thorax showed a diffuse shadow over the left chest. The chest was repeatedly aspirated, but no fluid was obtained. Bronchoscopic examination (according to the patient) showed a narrowing of the left bronchus due to pressure upon it. Left pneumothorax was induced. The chest was tapped again and again without result. The patient went home and some time later contracted a cold which intensified the pain and dyspnea. She recovered from this attack, but her condition became worse. Seven months after her first symptoms, she became more severely ill and was forced to go to bed. At this time she had fever, marked dyspnea, tachycardia, and severe pain in the chest. A month later intrathoracic tumor was diagnosed, and the patient was referred to the author. Upon examination by the author, the patient did not appear ill but seemed to have lost some weight. She was slightly dyspneic and had a hacking cough. There was no edema, ascites, or clubbing of the fingers. The thorax was observed to be markedly asymmetrical, and the left half of the chest bulged anteriorly. The cardiac impulse was displaced far to the right, and palpation revealed the apical impulse to be in the fourth interspace, 9 cm. to the right of the midsternal line. The respiratory movements were restricted over the entire left thorax. On percussion there was found from dullness to absolute flatness over the entire left thorax, both anteriorly and posteriorly. Breath sounds ranged from diminished to absent over the entire left chest. Cardiac sounds were feeble but normal; the rate was rapid and the rhythm normal.

Anteroposterior x-rays of the thorax showed a diffuse, ill-defined shadow almost filling the left thorax. The heart was displaced far to the right, the apex almost reaching the right lateral thoracic wall. Lateral x-rays revealed that the shadow did not occupy the upper thorax anteriorly nor the lower thorax posteriorly. The tumor was explored under local anesthesia. The parietal pleura was stripped from the thoracic wall, beneath which was observed a portion of an encapsulated tumor.

Palpation of the tumor gave the operator the impression that it was a cystic tumor. A large needle was inserted and 5 c.c. of yellowish, thick, mucoid fluid was aspirated. This fluid was subjected to microscopic examination, and it was found to contain fat droplets, fat cells, and a few epithelial cells. The diagnosis of lipoma was made. The tumor was incised, and a layer of material underneath the capsule 1 cm. in thickness which grossly resembled fat was observed. Beneath this layer there was a broken-down greenish-yellow myxomatous material which could be removed easily. Portions of the tumor were removed, and the wound was closed without drainage. The wound healed per primam. A further operation was proposed to remove at least a portion of the tumor, and perhaps to marsupialize the capsule. The patient was later prepared for operation but died while the infiltration of the operative field with novocain was being done. The patient died in a convulsive seizure which was thought to be due to pleural eclampsia.

At autopsy there was observed marked downward bulging of the left diaphragm and, to a lesser degree, of the right diaphragm. The liver was greatly displaced

downward. The thoracic cavity seemed to be completely filled with the tumor when the chest was opened. The tumor mass was smooth, yellowish, and more or less spherical in shape. The heart and lungs could not be seen. The greater part of the neoplasm lay in the left thorax, but posteriorly it filled the lower portion of the right thorax as well. There were few adhesions between it and the thoracic wall except at the site of the previous operation. The tumor, heart, and lungs were removed en masse, and together they weighed 12½ pounds. The tumor mass was found to arise from the anterior mediastinum. It measured 25 by 25 by 13 cm. After hardening, the tumor was sectioned, and it was found to be composed of an outer layer made of fatty tissue and a central mass of degenerated myxomatous material. The left lung was very small, totally collapsed, atelectatic, and completely flattened over the posterior upper margin of the tumor mass. The right lung was considerably encroached upon, but was crepitant throughout. The heart was small and atrophic; the pericardium was thickened and showed a fine fibrinous pericarditis. The posterior surface of the tumor was densely adherent to the anterior pericardium.

CASE 19* (Walker, R. Milnes[3]).—The patient, a white male aged 13 years, gave a history of weight loss over a period of three months. Also there was present a peculiar whistling noise which occurred as he breathed when asleep. For the two weeks preceding, he had been short of breath on exertion. There was no cough, and the appetite was good. Physical examination showed active dilation of the alae nasi and slight cyanosis. There was some bulging observed over the second, third, and fourth right intercostal spaces in front; the heart apex beat was in the seventh interspace, 11.5 cm. to the left of the midline. There was poor expansion of the right side of the chest, and the whole of this side was dull to percussion except a small area in the axilla. Breath sounds over the whole of the right side of the chest were bronchial in type, except for the resonant area in the axilla where they were vesicular. The breath sounds over the left lung were normal. An attempt to aspirate the pleural cavity failed to reveal fluid, but the needle passed into a soft mass. An x-ray of the chest showed a large rounded shadow occupying almost the whole right chest, except for a triangular area above the diaphragm in the axilla. This shadow extended across the midline and had a smooth rounded border 5 cm. to the left of the midline overlapping the aortic shadow. The heart was displaced to the left.

A preoperative diagnosis of mediastinal dermoid was made, and it was proposed to explore it with a view of marsupializing it. At operation a large yellowish tumor was seen projecting from the mediastinum, and it was covered with pleura. The lung was compressed to the size of a "fist." The tumor was lobulated and soft. The tumor was incised, and a large mass measuring 18.5 by 8 by 7 cm. and weighing 515 Gm. was removed. A drain was left in the wound. After a stormy course the patient was able to return to his home on the twenty-second postoperative day. The whole right side of the chest remained dull to percussion, and the breath sounds were poor.

The patient was not seen again for almost six months when he complained of increasing shortness of breath of a week's duration. He was now short of breath when sitting up in bed. There was a dull percussion note over the whole of the right chest, and the position of the left border of the heart was still the same. X-ray examination of the chest showed that the whole of the right chest was occupied by a tumor except for a small area in the costophrenic angle, and that the tumor had spread further across the midline above the heart.

Three months after operation the patient had greatly improved and could run about in moderation. X-ray of the chest showed that the size of the tumor was

no less than it had been previous to operation. The trachea was displaced to the left so that its intrathoracic portion was running very obliquely. The old wound was reopened, and the capsule of the tumor was incised; it was found that the tumor was breaking down and was partly liquefied. Fat could be removed from inside the capsule by the handful. In some places the fat was adherent to the capsule, but in most places it was easily detached and removed. The fat removed in this manner weighed 1.47 kg. Most of the tumor was thus removed. Twenty-one hours after operation the patient died. Death was probably due to cardiac embarrassment from the severely displaced mediastinum, augmented by anoxemia undoubtedly due to failure of expansion of right lung and edema of or pressure on the left bronchus.

REFERENCES

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3. Walker, R. Milnes: J. THORACIC SURG. **6**: 89, 1936.